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NSF AUTHORIZATIONS

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BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

SECOND SESSION

ON

NATIONAL SCIENCE FOUNDATION REAUTHORIZATION

APRIL 14, 1988

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NATIONAL SCIENCE FOUNDATION AUTHORIZATIONS

THURSDAY, APRIL 14, 1988

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The committee met at 9:30 a.m., in room SR-253, Russell Senate Office Building, Hon. Ernest F. Hollings (Chairman of the Committee) presiding.

Staff members assigned to this hearing: Pat Windham, professional staff member; and Mark Farrell, minority professional staff member.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. Welcome to this morning's hearing on the reauthorization of the National Science Foundation (NSF).

Our hearing last year focused on the critical role that NSF-sponsored research plays in our Nation's economic competitiveness. Advanced technology and a well-educated work force remain this country's one great competitive advantage, and we must nurture that advantage. This Committee remains very concerned about U.S. leadership in science and technology, and this morning we will explore the competitiveness-related programs of the Foundation, including the new Science and Technology Research Centers.

This year, however, we will also examine a second and related issue—the important role that federal research programs can play in promoting regional economic development and in raising the opportunities of all our people. If advanced technology is the key to economic growth, and research and education are keys to advanced technology, then we must ask what can be done to strengthen the science capabilities of universities and colleges throughout the country.

The issue has become particularly urgent in the case of minority students and women, two groups very underrepresented in science and engineering. With international competition growing more intense, not less, we as a Nation cannot afford to ignore entire groups of young people or entire regions of the country. We need the best possible work force.

The federal government cannot do everything by itself. Nor should we simply throw money at problems. But well-designed federal programs, working with the states and schools, can help build excellence in both research and education.

This issue of excellence throughout the country has come to the fore this year—largely because of the new debate over academic "facilities." From 1960 to 1970, NSF helped universities and colleges modernize their laboratories, and many education groups want NSF to undertake a similar effort now. They argue that obsolete facilities limit their ability to perform the research the country needs.

We on the Commerce Committee strongly support higher education; and, in consultation with our Labor Committee colleagues, we will consider these facilities proposals carefully.

I do want to make one point very clear, however. I will not support a facilities program which simply makes rich universities richer. These well-funded schools have legitimate facilities needs, and we will not ignore them. But facilities are a type of infrastructure, an investment in the future, and any federal infrastructure program must strengthen science and engineerifg capabilities throughout the country. I will insist that any NSF facilities program must help a wide range of universities, must help undergraduate colleges, and must help predominantly minority schools. Science is too important to leave to just the few.

We have a distinguished set of witnesses today, including a panel that will discuss the facilities issue. Our first witness is the esteemed Director of the National Science Foundation, Mr. Erich Bloch. We are pleased to welcome him once again to this Committee.

The nation as a whole is trying not only to play catch-up in the international community with respect to research, but also in the commercialization of that research.

We also are looking at a proposal included in the Labor and Human Resources Committee reported NSF reauthorization bill for "bricks and mortar," which starts off modestly in cost but goes up dramatically. And we wonder whether we should be building buildings or rebuilding our talent and other skills. And in any kind of rebuilding, to extend research capacities to the minority schools and previously neglected sections of the country.

We are always into this dilemma of the peers having all the peers. And incidentally, when they get all the bricks and all the mortar and keep on rebuilding, the rich simply get richer. And that disturbs us in the Congress, because we have seen, for example, in this committee a particular program, Sea Grant Program, work throughout the entire country.

Yes, Woods Hole and the others did a magnificent job up there, but then we extended it to all parts of the nation and it worked extremely well.

Let me yield to my colleagues. Senator Wilson.

OPENING STATEMENT BY SENATOR WILSON

Senator WILSON. Thank you very much, Mr. Chairman, first for your convening of this hearing today. The reauthorization of the National Science Foundation and its programs is not only of vital importance to my state, but to all states.

And indeed, absent the adequate support which Congress must provide for the National Science Foundation, I think the competi-

tiveness of this nation and the welfare of our citizenry would be distinctly jeopardized. I am especially pleased to have the opportunity to outline several specific concerns that I think must be addressed during the reauthorization process.

And I think that Dr. Bloch will have the opportunity to comment and probably feel compelled to comment on some of the issues that I want to raise.

As my colleagues on this committee know and as he knows, I have had more than a passing interest in the management of several NSF research programs, most notably those dealing with our national earthquake research program. For the benefit of those who have not been directly involved in the program, a brief synopsis of recent action may be helpful.

On December 31st of 1985, the National Science Foundation issued a program announcement to solicit proposals from institutions engaged in earthquake engineering research and related activities to operate an earthquake engineering research center.

Six proposals were submitted, only two of which were recommended for further review, one submitted by the State University of New York at Buffalo, known as SUNY-Buffalo, and the other by the University of California at Berkeley. In what I still believe to be an illogical decision, the National Science Foundation awarded a $25 million grant to SUNY-Buffalo to operate the center, despite express concerns by respected academicians from California and New York, from other members of the Congress, and from myself about the NSF review process.

A GAO report issued last year on the NSF decision for awarding the earthquake center grant, echoed some of these concerns. Specifically, the GAO concluded that existing documentation did not adequately justify the award to SUNY-Buffalo, nor were matching fund requirements made clear by the National Science Foundation.

In addition, NSF's use of a conditional recommendation created the appearance of prejudgment on NSF's part prior to a site visit to Berkeley. This apparent deviation from accepted peer review procedures is cause for concern.

Now, I would ask Mr. Bloch to indicate what steps have been taken to ensure that future NSF grant processes will adhere to merit review procedures. But first I would like to address several concerns I have with respect to the management of the present earthquake center.

By way of background, during the grant process to select the national center grant recipient, the NSF review panel recommended against a site visit to Berkeley because no commitment for matching funds was submitted with Berkeley's application.

Yet, as the GAO pointed out, the National Science Foundation program announcement for the center was ambiguous at best with regard to the requirement for matching funds. Therefore, the panel should never have made this recommendation.

Indeed, had it not been for the efforts of members of Congress to arrange a Berkeley site visit, a visit might not have ever been conducted.

The issue of matching funds has resurfaced once more. In this instance, SUNY-Buffalo is involved. I have in my hands an article which appeared in the Buffalo News on January 22nd, 1988, in

which Buffalo University President Steven Sample emphasized the lack of funding in Governor Cuomo's 1988–1989 budget proposal for the national earthquake center. In fact, Sample indicated that the center may become a political football.

In another article entitled "University of Buffalo Earthquake Center gets high marks, but lags on jobs," Robert L. Ketter, the Buffalo center director, indicated the center has already begun to turn down offers from companies interested in sponsoring research in such critical areas as earthquake-resistant masonry.

The reason is that the center has been unable to "get a certain stability," according to Ketter. At numerous points in the article, the center is said to be torn between a legislature that wants to create jobs and the National Science Foundation, which is primarily interested in research.

Perhaps the most alarming statement in the article is attributed to National Science Foundation officials. The article states: "The National Science Foundation is scheduled to review the center's performance in 1989, but Ketter said Foundation officials already have told him to assume the work will continue, regardless of whether the state contributes money."

Now, this is really an outrage, in light of the offered explanation for the failure to visit the Berkeley site during the time that the award process was in progress. Berkeley was denied a site visit because accompanying that application they failed to include a commitment for matching funds with their grant application.

Over a year later, according to Mr. Ketter, NSF officials appeared to be unconcerned about Buffalo's matching funds. There is a very serious discrepancy there.

If this is not enough to call into question the management of the national center, I would call to the attention of my colleagues an article written by Mike Vogel of the Buffalo News entitled "Center co-sponsoring major New York City conference."

In February, the center held its first major conference to assess earthquake damage on the East Coast. This is not unlike calling a conference to study hurricane damage in Kansas or marine life in North Dakota.

I would ask what we are doing. Perhaps Mr. Bloch would like to comment on this, spending precious Federal earthquake research dollars on an East Coast earthquake damage conference.

This chart indicates something of the absurdity of this. It is a record presented in graphic form of all the earthquakes occurring in the United States, from the turn of the century to the present, experiencing magnitudes equal to or greater than 4 on the Richter Scale.

It shows, for those who cannot see it, that in the Midwest and eastern states there have been a total of 255. By contrast, in the western and Rocky Mountain states there have been 18,681.

Now, I point that out, obviously, Mr. Chairman, because in light of the fact that there is such a tremendous difference in the earthquake experience on the East Coast and that in the western United States, we should simply make clear that the need is obviously minimal by comparison with what it is in the West, where this technology has been pioneered, where there is a professional community in place, and where clearly the need has existed and con-

tinues to exist for this kind of research, and where there are special factors that combine to make it most promising.

Further, many of the eastern seaboard states, such as Maryland, Rhode Island, Connecticut, Delaware, and Florida, have not had a single quake since 1900.

Now, while we expend Federal resources on conferences of the kind that is being organized in New York, what is occurring with respect to our research efforts across the nation and more specifically in California? As we know, California research universities have traditionally led the world in the field of earthquake engineering.

As a result of the state's research efforts, we have witnessed the most significant research breakthroughs and the nation has benefited accordingly from the training that California has provided to many of our current leaders in earthquake engineering research and practice.

Of equal importance, California has led the nation in the transfer of earthquake engineering research into engineering practice and policy. And yet, California research universities are currently struggling to remain on the cutting edge of earthquake research due to a lack of research funds.

This funding shortfall has resulted from an unwillingness on the part of NSF, which is the largest source of this type of funding, to increase funding on earthquake research, despite a 24 percent increase in NSF's research and related activities budget over the past ten years.

As the next chart shows, funding for NSF has increased from $857.2 million in fiscal year 1978 to over $1.7 billion in fiscal year 1988. Consequently, NSF support of research activities increased from nearly $778 million to over $1.6 billion during the same period, or an increase of approximately 25 percent.

However, during this ten year period total NSF funding for earthquake research as a percentage of the overall NSF research budget, has plummeted nearly 40 percent.

Now, what has been the result? At UC-Berkeley, the level of NSF-sponsored earthquake engineering research support has taken a nosedive from an average of $1.65 million annually to only $671,000 in fiscal year 1987.

At UC-Irvine, a newly constructed structures laboratory is not being utilized due to lack of funding. At UCLA, seismic tests of bridges and bridge components have come to a halt. At UC-San Diego, an NSF-sponsored testing facility will operate at only 40 percent capacity due to no real increases in Federal funding.

At Cal Tech, earthquake engineering activities have been negatively impacted. Graduate student enrollment is nonexistent. Only one new graduate student was enrolled for the 1987–88 academic year. Additionally, at Cal Tech all full time professional staff have been eliminated at the earthquake engineering laboratory, which is essential to the completion of structural testing and ground motion studies.

Finally, at Stanford the earthquake engineering structures laboratory has been idle due to funding shortfalls. And at USC, important ground motion monitoring efforts for southern California have been severely affected.

The clock is ticking, Mr. Chairman. The inevitable event is approaching. The lives of millions of Americans depend upon effective and properly focused national earthquake research efforts.

Regrettably, I do not have much faith in the current activities of NSF in this area, for the reasons that I have just detailed. And therefore I will seek legislative remedy to correct what I perceive to be an obvious and serious series of flaws.

I appreciate the indulgence of the chair and my colleagues in making a lengthy statement, which I only regret has been necessary.

Having said that, I look forward to the committee's markup of the reauthorization bill.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Senator Exon.

OPENING STATEMENT BY SENATOR EXON

Senator EXON. Mr. Chairman, thank you very much. I am going to be very brief with my statement.

I do want to welcome all of the members of the panels that we are going to have here today on a very, very important subject, and I think that the National Science Foundation has a key role to play in what we are going to do, if anything, about the mounting trade deficit.

In case you had not heard the news this morning, the trade deficit took a very sudden turn upward when all of the experts were projecting that we would see a continued downward trend.

I think the United States of America is in terribly bad shape, but there seems to have been some hesitancy to move forward with the trade bill which at least addresses this in some areas. The news this morning should put an end to all of that.

I just want to say what a tremendously important role most of us feel the National Science Foundation has to play in this latest economic menace to the United States and all she stands for. And we appeal to you to hang right in there with regard to the development of new technologies through science that will help the United States of America.

Mr. Chairman, I would particularly like to take this opportunity to thank you for your help in setting up this meeting and bringing in these experts to help us out as we review this measure before us.

As you recall, during the consideration of the Senate trade bill, I came to you, Mr. Chairman, with the idea of establishing a self-supporting technology trust fund which could provide additional long term resources to scientific research and development, particularly, Mr. Chairman, to the regions and schools which have difficulty securing funds from existing sources, because of course, there is an awful lot of competition for the money.

I would simply say to you, Mr. Bloch, that I have listened with great interest to my friend and colleague from California. As far as I know, the University of Nebraska and our other schools that are competing for funds out there are not interested primarily in research with regard to earthquakes.

But if you would assign us that task, we would be glad to take it on.

You have encouraged me, Mr. Chairman, in my efforts and advised me that the Commerce Committee's hearings on the National Science Foundation Reauthorization Act would be a good forum for the discussion of the legislation that I have proposed.

I hope that the panel has had the opportunity to consider some of the issues raised by my bill, S. 1302, the technology trust fund bill. I am hopeful that perhaps some type of pilot program could be worked out to test the concept of self-supporting trust funds for science and the effort to serve areas which have limited access to existing funds.

And I hope that the panels that we have here today will have an opportunity to comment on that.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Exon.

Senator Rockefeller.

OPENING STATEMENT BY SENATOR ROCKEFELLER

Senator ROCKEFELLER. Thank you, Mr. Chairman. And I also appreciate the chance to have Erich Bloch here. He knows, I think, very clearly that I think he is one of the best leaders that our government has, and I will do everything I can to support his authorization.

Later this morning, Mr. Chairman, we are also going to be hearing from Tom Courtice, who is president of West Virginia Wesleyan College. West Virginia Wesleyan is interesting in that it has done an outstanding job over the years of educating young scientists and engineers.

It is unusual for a school of its size to have a program in engineering, computer science, and a masters in engineering program with the University of Pennsylvania, but it does.

In fact, back in the 1960's West Virginia Wesleyan ranked ninth in the country for the number of Ph.D. scientists turned out by a liberal arts college. So there is a tradition of training scientists at Wesleyan.

Tom Courtice came to West Virginia Wesleyan last year. He has 20 years of experience in liberal arts colleges, particularly small ones, and we are pleased that he is here. And he is going to tell us later about his efforts to try and take a four year college and train students for science and engineering.

Mr. Chairman, in the not-too-distant past many of us regarded the National Science Foundation to be a highly academic, learned society that doled out grants to universities for esoteric scientific research projects. But that perception has changed radically.

There is now a consensus that our nation's economic growth rests on a vibrant and solid science and technology research base. We know now that new technology has been the key to nearly half of all productivity increases since World War Two, surpassing in fact capital or any other single factor for its impact on economic growth.

Despite this realization, Congress has not given the National Science Foundation, the lead agency in basic scientific research, the

money that it needs. Last year the National Science Foundation requested and I supported a 17 percent increase and a doubled budget over the next five years. The National Science Foundation received only a five percent increase last year.

This year the NSF has asked Congress for a 19 percent increase and a doubled budget. And again, I will support NSF's budget request.

I understand that our nation's budget deficits loom large. It is hard to look at the long term when our nation has pressing immediate needs, but we cannot afford to neglect the foundation of our future. We would be foolish to neglect basic science research and development.

Mr. Chairman, I would also like to take this opportunity to express my very real concern about a problem that I know our states share. I am the first to agree that we need to continue to invest our Federal dollars in the best research institutions anywhere.

The Stanfords, the MIT's, the Cal Techs of this nation are the reason that we lead the world in Nobel Prizes. They are the reason why students come from all over the world to study engineering and science at our schools.

Most of our states, however, are not fortunate enough to have institutions of that kind of preeminence within our borders. A National Science Foundation study showed that 20 universities, less than one percent of all higher education institutions in our country, account for more than 40 percent of the Federal funds spent on research and development.

But should there be nothing, Mr. Chairman, in South Carolina, in South Dakota, in Arkansas, in West Virginia, that is worthy of excellence? Is there not a scientific niche for the schools in these states also?

And how do schools like West Virginia University or Marshall University become excellent in research if funding agencies say to them that they "lack research tradition"?

I am not saying my state or any other state should be given a handout. I believe in the peer review system. In this age of increasingly worldwide scientific competition, however, our nation can no longer afford to waste human potential anywhere.

If the country is to prevail, we must mobilize all of our resources, not just the Northeast and California. It is not just the so-called second tier universities that need our help. We know that there is a severe shortage of American scientists and engineers and that we desperately need to expand the pool of our students in these fields.

We also know that undergraduate colleges train about 50 percent of the American students who go on to receive Ph.D.'s in science and engineering.

The success of our country as a whole in my judgment depends on the success of four year schools like some of our best ones in West Virginia, including West Virginia Wesleyan, Concord College, Wheeling College, and Bethany College, which in fact serve as our nation's pipeline for future scientists and engineers.

The EPSCOR program, a small program started within NSF in 1978, was designed to address the problem of the so-called have-not schools, Mr. Chairman. In many cases it has been very successful.

It is clear, however, that more needs to be done and that EPSCOR's one-time shot in the arm influx of funds may not be enough.

We cannot ignore any resources, and I look forward, Mr. Chairman, to hearing what must be a very impatient Erich Bloch.

The CHAIRMAN. Well, you will have to wait another minute, because now I am joining in Senator Wilson's statement and Senator Exon, and of course yours, Senator Rockefeller.

You woke me up when I heard you mention South Carolina. The fact is we have got something in South Carolina, and as you welcomed Dr. Courtice here from West Virginia Wesleyan, I would welcome our outstanding President of South Carolina State College, Dr. Albert Smith. He is to be on that next panel. He has an outstanding institution, and he represents the minority institutions. Mr. Bloch, as you well know, the undergraduate schools, including those four-year minority colleges, furnish half of those graduates who go on and receive their doctorates in engineering and science, and I am glad since you were the first engineer we could get to head up the National Science Foundation, you can nod in assent.

The record would show that the distinguished director is nodding in assent and agreement.

I have a statement that Senator Bentsen would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY SENATOR BENTSEN

Mr. Chairman, last summer you and I exchanged letters on the importance of increasing U.S. research activities by the NSF in the area of superconducting materials. I hope that our Committee will agree to additional funds for this purpose.

In recent months, there have been further dramatic advances in research, but NSF reportedly is spending only about $3 million more than last year. Just this week, *Science* magazine reports that American and Japanese scientists have now discovered "triple digit" superconductors—materials which become superconducting at temperatures above 100 degrees Kelvin.

Unless we step up our research in superconductivity, we risk falling behind. The Japanese are not sitting still. In fact, a Japanese physicist told a conference in Houston in February that government and industry were collaborating closely on a $120 million program in superconductivity. The Japanese are predicting that they will have magnetically levitated passenger trains running within two years. Japanese firms have filed for more than 800 patents for new superconductors just in the past year.

The commercial opportunities in this emerging technology are mind-boggling—for transportation, computers, medicine, and energy. For example, superconducting materials could cut the operating costs of electricity generation by 60 per cent and could allow us to increase our capacity 15 per cent without building any new power plants.

I want us to lead in this field, to gain a competitive advantage over other nations, and I believe we can if we provide the resources to our best scientists so that they can do the research they are eager and able to do.

The CHAIRMAN. So you know more than ever that you are welcome.

We will hear from you now, sir.

STATEMENT OF HON. ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. BLOCH. Thank you very much, Mr. Chairman. I appreciate the opportunity to be here to discuss the budget request for 1989. I also appreciate all the comments this morning from you, Mr.

Chairman, as well as the other distinguished members of your committee.

Some comments I appreciated more and some of them less, but I think that comes with the territory.

I would like to take a broad view for a minute. I am sure we are going to get into many of the other questions that were raised this morning, including earthquake engineering research centers and so forth, but I would like to take a very broad view for a minute and talk about our request before you and the reasons behind it.

As in previous years, we are proposing a budget that emphasizes the importance of science and engineering to our national economic well-being. During the past few years, the debate over economic matters has come to focus more strongly on science and technology. Increasingly, we understand that we must look to our own research, industrial, educational and governmental institutions to make us competitive. No one will do it for us. This understanding is only a first step, but it is an important one.

We are not satisfied, however, with the actual progress we have made in strengthening our research and educational systems. Although there is a growing consensus in recognition of the need, our fiscal problems have so far prevented us from taking the actions we must. I hope this can be the year when that changes decisively.

Science and technology are concerned mainly with two of our most important national goals, economic prosperity and national security. NSF focuses strongly on the former, namely, economic prosperity. We support science and engineering in ways that contribute directly and effectively to national economic competitiveness.

There are three important elements of science policies that are expressed in the NSF budget request and in the NSF programs. The first one has already been mentioned this morning: the development of human resources, because people are our most important asset.

Second is the support for university basic research because universities are the main source of new knowledge.

And third, the efforts to link the universities more tightly to industry in order to use our technical resources more effectively.

People must be the first priority. Trained and educated people are the major resource of any modern society. We are all pleased with the resurgence of the education programs of the Foundation and the general focus of our programs on human resource development. Support for science and engineering education has risen from $16 million in 1983, to a requested $156 million in 1989, almost a tenfold increase.

This is the sort of dramatic progress that we need. Also I want to point out that the pre-college area has increased from 7 percent of the Science and Engineering Education (SEE) budget to about 70 percent of that budget.

Our proposed 1989 budget request again makes human resource development a major theme. We propose a total investment of $265 million, up more than 20 percent over 1988.

The pressing problem is to attract enough students to science and engineering, because if we do not, we will have a shortage. Less than a quarter of high school graduates are qualified to do col-

lege level science or engineering. In the long run, stronger pre-college programs are a necessity. That is why we are focusing on this very important area.

Everyone who will complete a Ph.D. by the year 2000, however, is already well along in high school. Thus, we must concentrate our efforts on the undergraduate level and above in order to stimulate more of them to choose science or engineering careers.

I will refer to Figure 2, attached to the testimony that you have in front of you, that shows in a very dramatic and graphic way the leakage along the whole education pipeline, high school all the way up to postgraduate or to at least graduate degree Ph.D.'s.

And you see that in this pipeline there are three major leakage points. The first one is in the high school sophomore area when the science and engineering interest must be expressed by the individuals, in order for them to be prepared to go on to a degree in either the sciences or in engineering. The second leak occurs in a dramatic way during the entry into the undergraduate curricula, and the third one, at the end of the undergraduate curricula when it comes to making a decision to pursue the graduate studies or not pursue them.

And you see that in this total pipeline there is a 500 to 1 fallout rate from high school sophomores all the way to Ph.D's, a very large number.

A large part of any solution to the people problem must come from broader participation. We have made some progress in encouraging women to join the science and engineering community but we are far from where we should be, and there is some evidence that the participation rate is leveling off—leveling off, I might add, at a low level. We need to continue our effort to make the physical sciences and engineering more open to women. We have programs that address that particular problem.

With minorities we have had even less success, although in time the Minority Research Centers of Excellence may have a very important effect. The problem here is principally that too few minority students have adequate pre-college or undergraduate preparations. We are making special efforts to work on this particular problem.

A good example is the cooperative effort led by the University of South Carolina to train better science and mathematics teachers for the schools. By the way, the principal investigator on this particular program is an Assistant Provost of the University of South Carolina, which shows a lot of dedication. The program involves significant numbers of minority teachers in summer workshops and other training activities, and it has stimulated major state and university support.

In addition to concern for people as individuals, we must be concerned with the institutions in which they work. This means that we must broaden participation beyond the institutions that already compete well. That has been said this morning already. NSF has sought to do this, especially through the EPSCoR Program, but not only through the EPSCoR Program, with encouraging results. A point that is not well known and that I want to stress is that NSF is especially important in the states that receive relatively little Federal R&D support. We provide about 10 percent of the total

going to the bottom 10 states, compared to less than 3 percent that NSF provides of the total for the top 10 states.

So we have looked at the problem of broadening participation of individuals as well as institutions from smaller states, and I think, as you can see from the statistics that I just cited, it is not an empty promise. It is being borne out by complete results.

The second requirement for better economic performance is a stronger university basic research capability. I would hope that 1989 is a year in which progress in this area can match what we have recently accomplished in human resources. University basic research is more important today than ever before. The world is rapidly shifting to a knowledge based economy, and in our system, new basic knowledge is produced mainly in the universities.

In contrast to education, however, this support has not been rising in recent years. In constant dollars, in Figure 3 attached to the testimony, the NSF research and related appropriation for 1988 is almost exactly where it was in 1985. So we had a four year period with no real increases in the research and related area.

Federal investment in basic research and in civilian R&D has grown slowly and erratically in the past few years, while the research investments by our major trading partners have advanced strongly, as you can see from Chart 4 in my written statement. You see essentially West Germany and Japan exceeding us in growth.

In nearly every field that NSF supports, the opportunities to make important advances have outrun the available support. That is true in superconductivity, it is true in mathematics, it is true in biology, it is true in many areas of the manufacturing research arena. We are creating a great deal of new knowledge, but the demand for it is almost without limit.

The recent press reports on ozone and chlorofluorocarbons, for instance, describe a problem of immense proportion. It will take a lot of basic research to find a solution. It took a lot of basic research to find the problem. We must understand the problem better in all its details, which means much greater investment in the earth, ocean and atmospheric sciences.

I would also note that our Antarctic research program, a basic research effort that has been going on for many years, as you know very well, has been the source of our knowledge of the ozone hole over the South Pole, and that knowledge was a catalyst for much recent activity among policymakers.

The world is in an unprecedented period of technological development. We know that nothing like the present has been seen before, and a reasonable guess is that the future will be more intense and fast paced. In this situation, any nation that wishes to lead economically, militarily or politically must also lead in science and technology. This is impossible without rising levels of basic research support. Unless the United States is willing to cede its tradition of world leadership in science and engineering to others, we must find resources for the necessary investment.

The third area that I mentioned before was the linkage between universities and industry. Effective linkages among the various sectors of our economy is the third element of an effective science and technology policy, and the third theme of our proposed budget and

of many of our programs. This is especially important in the United States because our system is built on the research university. This keeps research and education tied closely together, which is a major strength and one of the reasons why our universities are the best there are.

But in this, as in other things, there is no free lunch. The drawback of our system is the tendency for university research to be isolated from economic reality. We need explicit mechanisms to make sure this does not happen and that the results of our laboratories flow smoothly into industry.

NSF has been a leader in developing new ways to bring the various players in science and technology more closely together. Our Engineering Research Centers, the first of which we established in 1985, have stimulated significant industrial and state support and brought new resources to the universities.

Each NSF dollar has been more than matched by industrial contributions and state support. Even more important is the contribution by industry through its people to make the centers work. This is especially crucial to knowledge transfer, getting new ideas out of the university into practical use. The only good way of doing it is through peer-to-peer contact across the lines that are separating us organizationally.

Our budget for 1989 requests funding to extend the ERC concept to other areas in science. We propose a new appropriation of $150 million for Science and Technology Centers, sufficient to fully fund 12 to 15 centers for up to five years. Universities have submitted some 350 proposals, with industrial commitments included in about 70 percent. This is a strong indication that both universities and industry see a need for these centers.

We hope that Congress will not disappoint us or industry and will support this request.

Mr. Chairman, I know the issue of our needs in academic facilities is of interest to this committee, and I would like to take a moment to restate our position. As I testified last year, the Federal government does have a role in supporting academic research facilities, which derives from its role in supporting the majority of the nation's basic research in science and engineering. NSF's position on its role in supporting facilities has been constant in recent years. We will consider facilities in competition with other proposals in any given field, but we will fund them only when it is clear that progress in the field depends more on facilities than it does on people and equipment.

In practice, this means that we support many specialized facilities such as telescopes, oceanographic vessels and supercomputers, but few facilities of a more general nature. In facilities as in all other cases, we must set priorities, and it is abundantly clear that our priorities must remain people first, equipment second, and facilities third. To divert currently available resources from either people or equipment to support facilities instead—and there is no other choice in today's economic context—would be contrary to the best interests of science and engineering, and therefore of the nation.

This is especially true because of our level budget for four years for research and equipment that I referred to previously.

Before turning to your questions, I would like to point out a few special aspects of our 1989 authorization bill. First, it is important that we have an authorization bill. I understand the situation that made it impossible to pass a bill last year. I just want to emphasize to you that having the judgment of this committee and the Congress as expressed in the authorization bill is important to the Foundation.

Second, I would point out that once again we have submitted a draft five year bill. This proposed authorization bill reflects the commitment of the Administration to a doubling of the Foundation's budget over the next five years. This kind of commitment from the OMB is rare, as you know, and it is important that it receive the endorsement of your committee. Passage of a five year bill would not preclude annual review of the Foundation by the Congress, obviously, but it would provide important recognition of the need for a long term approach to the health of the nation's scientific base.

In closing, Mr. Chairman, I would like to say something about responsibilities and priorities. Within the Foundation there is a constant need to make our programs fit the available resources. We cannot accomplish everything, and we must constantly reassess existing projects in order to make resources available for new ones. This is more difficult in a tight budget year, but it is also more necessary, and we have made specific choices. For example, we delayed the start of the Science and Technology Centers from 1988 to 1989, and we are undertaking a review of the astronomy centers and many other things. Some of these priority choices produce a reaction in the community, but that is really an indication that we are making meaningful choices.

It would be easier to simply decrease everyone's grant by an equal percentage, but that would not serve either the nation or the community well in the end.

The Congress has the same problem. We understand there are needs other than science, and you must judge their relative merits. But I would point out that nearly all Federal missions depend on scientific and engineering expertise and will benefit from new knowledge and new technology and the people that we are educating through our programs.

This is especially true of the space station, the supercollider and other major scientific and technical initiatives. NSF provides the base on which the success of these other programs will be built. Providing that base is what the Foundation is all about. That is why I strongly believe that our request needs and deserves your priority and your full support.

Thank you very much.

The CHAIRMAN. Well, I thank you very much, Dr. Bloch. That is an excellent statement.

I think all on the committee are prepared to go along with your points but with perhaps a few changes in emphasis here or there. I am not going to use the clock here this morning, but I hope the members will limit themselves. With the number of Senators we have, we should be able to do it.

Specifically with respect to the amendment placed in the bill over at the Labor, Health and Human Resources Committee, concerning facilities, what is your comment on that?

I understand and agree that first we have got to have the people, and then you have got to have the equipment itself, but I have not found any money left over for bricks and mortar myself. I still do not think in the limited endeavor and approach that we have, that we can do that, but maybe you have a different idea now that the committee added that amendment.

I would like to get your comment.

Mr. BLOCH. Well, I just want to make a few general statements. I will not deny the fact that there is a problem when it comes to brick and mortar in universities, not only in the research area, but also in the undergraduate area.

We have looked at that problem over the last couple of years in detail. If you remember, last year we presented to the Congress the results of a survey that we had made. We sampled the university requirements for facilities across the country. We are in the process right now of following up that survey with a much more extensive one, which is to be completed in the fall of this year.

So we have looked at the problem.

I reviewed that first survey, and so did the National Science Board, which must consider the problem as a part of overseeing the Foundation. We concluded together that the facilities problem, while it is a problem, is not as bad as it is sometimes being depicted. Most universities that have buildings planned do plan to support the buildings, either through state funding or through private funding. So it is not that nothing is going on.

Even so, it is true that the Federal government is not spending any money to speak of except in some very specialized areas. We are spending, for instance, about $60 million per year on facilities which are very specialized, like telescopes, supercomputer centers and so forth.

We came to the conclusion by looking at the requirements for facilities, that we were on the right track by focusing our limited resources. I made that point before, on people and equipment.

Let me just reflect on the equipment problem. When I first came into this job three and a half years ago there was a hue and cry and a lot of conversation in the community about lack of instrumentation and lack of equipment. Some of that is still going on, but I think the volume level of complaints has gone down significantly. Why? Because for one thing—and by the way, it is true about other agencies also—the Foundation has increased its spending on instrumentation to the point where today it is approaching 20 percent of our research and related expenditure whereas maybe ten years ago it was significantly less. So we have made some of these adjustments that were very important.

I do not know where to squeeze out money for facilities out of the existing budget.

With regard to the amendment that you mentioned, I want to make a couple of points. First of all, I appreciate one aspect of it, namely, a requirement that we look at that problem in its totality and that we spend a year on the planning of a facilities program. I think that would be very helpful, and I think that would be very

necessary because it is also true that the Federal government by itself does not have the total responsibility.

I mentioned before, states and the private sector. Both of them contribute today to the facility solution and need to continue to contribute to it. So I appreciate that part of the amendment.

The CHAIRMAN. I like your answer because that shows a sensitivity. That amendment was put on, as I understand, by the institutions of, let's say, not only higher learning, beyond the four-year undergraduates, but the richer schools. They want to modernize. Yet I am thinking of our astronaut that we lost in the *Challenger,* Ron McNair. After he graduated from a very little, modest country high school, he goes up to a four-year North Carolina college—we have got South Carolina State, they have got North Carolina Technology, a four-year minority college. Then he gets into MIT.

I will tell you right now that North Carolina and South Carolina do not have the equipment. So before we start modernizing the rich or making the rich richer, really what we should be doing is focusing on talent and equipment. Because the personnel are in many places, as you and I have just agreed, and half of them come from the undergraduate minority schools who go on for their doctorates. There comes all this talent down the line without even equipment.

I think before we start enriching or modernizing the rich, we had better try to get some extension out into the minority schools, into the four-year undergraduate schools by way of equipment before we start bricks and mortar.

Mr. BLOCH. Well, if I can comment on that particular point, and I wanted to make this point before—you are focusing on the undergraduate part of the system. You should know that over the last two years we have significantly increased the undergraduate programs in the National Science Foundation, despite the fact, as you mentioned yourself, that last year we had about a 3 percent bottom line increase on the research area, or 5 percent on the total Foundation. We have gone from almost nothing a few years ago to about $64 million in our request today for undergraduate education, and that includes not only curriculum development, which is very important, but it includes instrumentation. Instrumentation in the undergraduate area is in a very sorry state as you know well.

The CHAIRMAN. Right.

Mr. BLOCH. So we have focused on undergraduate education in a significant way. As I said before, we have a double mission in the National Science Foundation. We are to make sure that the country stays at the leading edge of research and of technology. That is one mission. And the other one, is to make sure that we are broadening the participation. There are many reasons for this, economic reasons, equity, you name it. The fact is that we need skills. Our base for skills is going down. Look at the decline in the 22-year-old population. I think the Foundation has the obligation to do both of these things. It is not one or the other. And the two are not in contradiction in my opinion. We need programs on both sides, and we need to keep the right balance between the two.

Both of these areas need strengthening, no doubt about it. We are not where we should be.

The CHAIRMAN. Very good.

I am going to yield to Senator Wilson.

Senator WILSON. Thank you, Mr. Chairman.

Mr. Bloch, let me ask you first of all, since I have commented on it, I would like to afford you the opportunity to respond.

What is the explanation for the discrepancy between the requirement for matching funds that I noted in my opening statement? There was almost no site visit arranged to the Berkeley campus, and yet scarcely a year later we find that there is no interest on the part of NSF in the requirement for matching funds. A statement by Mr. Ketter indicated that.

Mr. BLOCH. Well, Senator, that last comment you are making bothers me greatly because it is not true. There is a great interest by the National Science Foundation in making sure that the institution, in this case Suny-Buffalo, complies with its promises, especially the matching fund promise. I do not know what the situation is this minute, but let me tell you that in 1987, where we put in $4.2 million, Buffalo fulfilled its commitment beyond what they promised. They promised $5 million, they put in $8.5 million from various sources.

Senator WILSON. So you are disputing the statement that was made?

Mr. BLOCH. I dispute the statement for 1987. I cannot dispute the statement for 1988, because I do not know. But let me tell you that we are following that particular program in great detail, just as we are following every other program, in great detail. Buffalo is under the same scrutiny as everybody else, and I really do not believe that we are neglecting our duties in that regard. We made an agreement with Buffalo, and it was partly based on their proposal of matching the funds, and the excellence of the proposal, that they got the award. They have a promise and they have a commitment to match our $5 million year by year for five years.

Senator WILSON. Well, evidently they are not doing it, so I think that we need to pursue that because the statement here has been made, as I indicated in my opening statement, that Foundation officials have already told the center director to assume that the work will continue, regardless of whether the state contributes the money. That is a direct quote.

Mr. BLOCH. Well, there are lots of quotes in lots of papers, and I am always suspicious when people talk to papers. But let me tell you——

Senator WILSON. This is the center director.

Mr. BLOCH. Well, I am not responsible for the center director. He is responsible to us. But let me tell you that we have a strong program in place which we are exercising in the Engineering Research Center area that is looking every three years at how a center is performing, and we are going to do exactly the same with the earthquake research center in Buffalo. If they do not perform, they get closed down.

We just closed down two Engineering Research Centers out of six because we were not satisfied with their progress. The same approach, the same scrutiny, the same evaluation will hit Buffalo three years after its start.

Senator WILSON. Well, I am delighted to hear that because you are going to have help. We are going to watch it with you.

Mr. BLOCH. I know you have watched us, and by the way, we appreciate that.

Senator WILSON. Happy to oblige.

Mr. BLOCH. I think we have improved our operation and our procedure because of your help.

Senator WILSON. Well, let me see if I can help further.

In your testimony, you state that "American manufacturing appears to be starting a comeback, as it must if we are to prosper. But manufacturing will change dramatically over the next decade as new materials, computer aided engineering design, robotics and other new technologies emerge from basic research."

Now, after reading the statement, I am at a loss to understand why, having given the emphasis that you do, and I think properly, to the role of robotics in improving our manufacturing capability and our engineering capability, why is it then that the National Science Foundation has made the decision to shut down the Center for Robotic Systems and Microelectronics at the University of California at Santa Barbara, a site where your panel, in its report to the National Science Foundation, stated "It is the opinion of the panel that the successful implementation of the proposed center program would definitely be in the national interest. Further, there is significant evidence that this center will be able to carry out this important program. The center funding should be renewed."

And as you are aware—that is the end of the quote—the research that was being conducted there at the Microelectronics Center, the Robotics Center at UCSB, is designed to improve the efficiency of a specific industry that is critical to our nation's defense as well as to our competitiveness in the whole microelectronics field.

It is absolutely critical that we improve the ability to produce quality, cost-effective microelectronic components. And acknowledging that importance in your statement, I am at a loss to understand why it is that the Foundation has at this moment decided to terminate robotic research in a basic industry about which we have been so concerned that in the past year the Department of Defense authorized the hybrid Sematech to make certain that we would not be dependent upon a foreign source for that high technology.

Mr. BLOCH. Senator, that was exactly the center I referred to when I said before that we are closing down two centers. By the way, let me just state for the record the facts. We are not closing them down tomorrow morning. It is a two year phaseout. We committed to five years. The evaluation was after three years. The evaluation outcome would have been the decision to continue or not to continue. We are not closing them down tomorrow. We are phasing them out over two years, point number one.

Point number two is the following. Nobody knows better than I do, because I came from that industry, how important components, clean rooms, and robotics are in making these sophisticated processes work. We are not developing processes in the National Science Foundation. We are developing basic research. That center was put in place with the idea that they would have an outstanding record of research accomplishments.

After three years, that has not turned out to be the case. That is why we are closing it down. It is also very important, by the way, that we are looking at the excellence of the results and not just putting money into robotics because it is an important area. It is important, no doubt about it. But unless we have excellent programs, I think we are wasting money. The decision was based on the fact essentially that that center and another one in a different area—and I do not want to name it, obviously—did not perform to our satisfaction.

I think we have the responsibility in the National Science Foundation to look very closely and see that taxpayers get value for their dollars.

Senator WILSON. Well, what I find hard to reconcile is the statement by one of your peer review panels that the NSFPDs agree with the panel recommendation that the Santa Barbara ERC, the center should be renewed conditionally, but the comment has been made that the panel was very favorably impressed by the education component of the center. It is the opinion that successful implementation of the proposed program would definitely be in the national interest. The center has done an outstanding job in motivating students and creating a very exciting environment for students.

The center's efforts in interactions with industry has also been in that correct direction.

Mr. BLOCH. Senator, I have looked at the report myself, and the National Science Board has spent untold hours on all six of these centers, let me assure you. There is no doubt that Santa Barbara did a good job in the education area, but it did not do as good a job as it should have done and could have done in the research area, and that is why it was closed down.

The panel report is a recommendation. There are other things that are being taken into consideration. It is a comparison between centers which is very important. And it did not measure up to our expectation.

I regret it, by the way, because I personally had high hopes for that particular center. As I said before, I like that area of research; it is a very important area of research. It is a very economically competitive area.

You mentioned SEMATECH. But I think we have got to look at the excellence and at the quality of the science and of the engineering that is coming out of our universities.

Senator WILSON. Do I understand that there are six robotics centers across the country?

Mr. BLOCH. No, I did not say that. I said there were six Engineering Research Centers that were evaluated, because all six had been in existence for three years. The center in Santa Barbara is the only center on robotics among the six.

Senator WILSON. So we are presently without any, if that is being closed down?

Mr. BLOCH. Well, let me say this. We are presently without a center. I will come back to that in a second. But we have a lot of work going on in the robotics area, individual grants, group grants in both our engineering area as well as in the Computer and the Information Science and Engineering directorate. We are not with-

out robotics work. By the way, that center was specialized for a clean room environment. It was not a general robotics center, and it did not pretend to be. But it was specialized for a clean room environment.

Dr. Moore would like to make a comment.

Dr. MOORE. Senator, there is also an Engineering Research Center at Purdue on intellegent manufacturing systems that is doing work in robotics, although that is not their central thrust. So this is not the only center that was engaged in that kind of research. But as the Director has said, there is a good deal of research in related areas going on throughout the Engineering directorate and across the Foundation. In our 1989 request in the manufacturing area, we are projecting between $40 million and $50 million.

Mr. BLOCH. We would be glad to break that out for you so that we can show you what we are spending on robotics. We would be glad to supply you with that.

Senator WILSON. Well, let me ask you—and this will be my final question, Mr. Chairman—you do not share the concern that I obviously have about the list of terminations or curtailments on the part of basic and very critical engineering research into earthquakes that have been required of these various institutions in California.

I must tell you, Mr. Chairman, that this is a matter about which Californians grow emotional because we experience quakes with some regularity. We take the small ones in stride. But we are very much concerned with the necessity to develop the kind of expertise that will permit not just survival but the avoidance of the real tragedies that we have had in the state. To successfully avoid those tragedies in the future, obviously we require knowledge that can come only from basic research on structures and on soil, and the things that I have listed in my opening statement that are critical to gaining that kind of knowledge.

Now, it seems to me that—and incidentally, I must say that California makes a very substantial investment, and we always have. Obviously we do because it is in our own self-interest, but at a time when we are constrained and at a time when research is going up, I must say that I think that we do a great deal of talking about priorities, and yet the kind of technology that permits large segments of the population to survive is, in my judgment, an urgent priority.

So I have to ask why is it that we are cutting back in such a way that causes the cessation altogether or the curtailment of these basic engineering research programs upon which life will depend.

Mr. BLOCH. Well, let me first give some facts.

In 1987, we spent $25 million on earthquake research through two directorates, the Engineering Directorate, obviously, and the Geosciences Directorate.

If you look back in time to 1986, for instance, it was $22 million or $23 million. If you look at 1985, it was $25 million. So the numbers have stayed pretty constant.

The other thing which I mentioned before has happened, that in FY 1987 where we started the Buffalo center to the tune of $4.2 million, there was another $8.5 million that went into that center

from other sources, because we established the center, from the state and other sources.

So really, it was $33 million that we spent on research, if you include this $8 million.

Secondly, I went back and looked at how much we are spending in California, and in 1987 we spent $8.4 million in California on earthquake research. Let me give you the New York number. The New York number is $7.4 million.

So I think we are pretty well split.

Senator WILSON. Well, let me give you the number that I gave you before, and that is the difference in the presence of the threat. I mean, there just have not been very many threats on the East Coast, and there is an enormous, constant threat in the west.

Mr. BLOCH. We did not put the center in the east because of a threat. We put the center in the east because the proposal that we got from there was better than the one from Berkeley. And by the way, I do not think there is anything wrong with broadening the community of researchers. I think the worst thing we can do is depend on one community only, isolated by itself.

Broadening it, having people coming in from New York, Missouri, and other states and supporting research in earthquake engineering, in earthquake sciences, I think is a healthy thing. If we have done that, I think we probably in the long run have done everybody a favor.

So we did not put the center where the earthquakes are, but where the knowledge is, the interest, the quality was that came through in their proposal.

It is a fact, you know, that it was between two states, no doubt about it, and one lost. We had only one center, so one had to lose.

Senator WILSON. Well, Mr. Chairman, I must tell you that I am glad that the hurricane center is where it is, and I think there is no accident as to why. It is because that is where they experience the threat, and as a result, that is the reason that expertise has lodged in that area.

The same thing, I have got to tell you, is true in spades with respect to the presence of a professional engineering community that has specialized in earthquake study, with respect to faculty, with respect to research, and there is definitely a need to on a broad front achieve the kind of education that this country is beginning to lack in serious ways in terms of engineers and scientists.

On the other hand, I would have to say that I think that when we are constrained, as in fact we are, we do need to set priorities about the kind of research that cannot be duplicated. We are not going to have a supercollider in every state. We are not going to have a hurricane center in every state. And it seems to me that what makes sense is to look not only where the threat is, but where the experience has been and where a body of knowledge has built up, and in time of instant communication, that information can be shared with the entire world.

But I think that there is a great deal to be said about maximizing existing resources to achieve the maximum benefit for the American people. And we cannot be porkbarreling basic research dollars.

Mr. BLOCH. Could I say one more word on that?

The Buffalo center—and you mentioned the conference in New York City—has as one of its jobs to make sure that the transfer of information takes place between the research and the user end of it. That is what that conference was all about, by the way. So they had a very strong component in their proposal of transferring that information, which was one of the reasons why that proposal was judged to be very outstanding.

But let me assure you, Senator Wilson, we are taking that job as seriously as we take any other job, and we make sure that Buffalo lives up to its commitment, both to its financial commitment as well as to its technical commitment. I want to assure you of that.

The CHAIRMAN. Thank you, Mr. Bloch.

Senator Rockefeller?

Senator ROCKEFELLER. Thank you, Mr. Chairman.

As I indicated, Mr. Bloch, EPSCoR is obviously basic because its philosophy is that you have to have a science and engineering base in this country, and that not every state has an equal base. Therefore EPSCoR tries to go in and create a base based upon grants, and it lasts about five years.

Now, I happen to think that EPSCoR is really important in terms of training our engineers and scientists, and obviously you do, too. Interestingly, it is a program which is not line itemed, so to speak, in your budget. It is within another budget, which concerns me, but my question of you would be, do you think there is a way that we can make EPSCoR more visible, highlight it more, and perhaps follow up after the five-year period has concluded?

What are your thoughts on that, Mr. Bloch?

Mr. BLOCH. Well, let me speak to that. You are right in your first comment, that EPSCoR is not a line item in the NSF budget.

It should not concern you because there are many things that are not line items, in the Foundation's budget that go on very well. We compensated for that fact, however, by setting up a staff in the Foundation to look at EPSCoR and make sure that EPSCoR works well, that the strategy is in place, that follow-ups are going on, visitations are going on. These are very dedicated people. They do not control the dollars—it is not in their budget, essentially, to control the fortunes of the EPSCoR program.

On your second point, making it more visible and also continuing it, I spent a day or a day and a half in Oklahoma about three or four months ago where all the EPSCoR coordinators from the various states, both states that are in the program today and that were in the program in the past, like your own state, for example, were assembled to discuss what is going on in EPSCoR and to learn from each other. The point that they made to me was the same point that you are making that there should be some kind of a continuation.

We are looking at that. I do not know what form it will take, but we are looking at that to see how that can best be implemented.

The original concept was a five year grant. After that it is up to the individual universities in the particular state to find their way into the normal process within the National Science Foundation. And by the way, some states have accomplished that, and some individuals have accomplished that and have succeeded very well in that regard.

But I think there is something needed beyond that, to make sure that the EPSCoR approach stays alive in all of these states that we have invested a lot of money and they have spent a lot of money themselves, since it was a matching fund program.

So I agree with you, and we are looking at that.

Senator ROCKEFELLER. Good. I hope that that dialogue can continue between the two of us, as well.

We have just, as you know, Mr. Bloch, concluded a new science and technology agreement in principle with the Japanese—it is not signed yet. It is being still worked out, but primarily it is agreed to, and the idea is to get some sort of reciprocity of exchange. Our scientists and researchers have long complained that they do not have access to Japanese laboratories where obviously superb work is going on. Meanwhile, we have up to 13,000 Japanese researchers at our Federal labs and state universities and first class facilities. There ought to be reciprocity.

Now, the Japanese come back, and they say that we would like to have that ourselves, but quite frankly, your American researchers are not interested, that they do not take the opportunity, they do not want to come to our laboratories, they do not speak our language, and that they do not make the effort either to speak our language or to show an aggressive instinct to come to our laboratories and learn along with us.

Are their criticisms correct?

Mr. BLOCH. Well, I am sure they are in part correct, at least.

By the way, you are right, there is an agreement that is just about to be signed. It might get signed in Toronto. It really is trying to put the relationship between Japan and ourselves on a more equitable basis when it comes to science exchanges and access to laboratories and so forth.

We have taken a very strong position in bringing that about. For instance, two years ago we negotiated an agreement with ICOT—a fifth generation program in Japan, a very prestigious program in computer science—to open that laboratory to some visitors from the United States, and by visitors we do not mean just to walk in and walk out, but be there for six to twelve months. We made that agreement three years ago. We are just now putting the first individual over there, so it took a long time to make it happen.

With Japan, we have been seeking two things. We want a quid pro quo whereby Japan will finance more of this exchange. Just as we are paying, as you mentioned yourself, for their people, they should pay for our people.

I should tell you that we received $4.8 million from the Japanese Foreign Office a few weeks ago devoted to funding American researchers to go to Japan to either universities or government or industry laboratories, if that can be arranged. And out of that funding of $4.8 million, we think we can make about 100 or so visits over a period of time.

We also have established a training course in the Japanese language, which people can apply for. We had a small group last year during the summer doing exactly that, about 15, 16 people. We are probably going to repeat that this year.

Senator ROCKEFELLER. At the Foundation?

Mr. BLOCH. Not at the Foundation, no. That is being done together with AEA, which is American Electronics Association, at a university.

Senator ROCKEFELLER. Is that the one at MIT?

Mr. BLOCH. Yes, last year it was at MIT, that is right. I do not know where it will be this year.

So we are trying to do two things, essentially. We are trying to have the government of Japan provide more of the resources for our people to go over there, and that is only proper on a quid pro quo basis, because we are paying for the researchers they are sending over here in many cases, not in all cases, but in many cases.

Secondly, we are asking them to open more laboratories, and we are in the middle of that particular process. We have targeted the MITI laboratories. As you know, the MITI laboratories in Japan are highly prestigious research laboratories. The electronic laboratory in Tsukuba Science City, for instance, is a prestigious laboratory in robotics and computer science. We've never had people in that laboratory. I think I was the first one who even walked through there in 1980, it was that closely kept. And we are just now negotiating with MITI to open up many of their laboratories so that we can take some of that $4.8 million, and send people even to these laboratories, and not just the ones that are open today.

Senator ROCKEFELLER. Mr. Chairman, I have other questions, but in the interests of time, I will submit those to Erich Bloch if that is all right.

And I thank the Chairman.

The CHAIRMAN. I appreciate it, and I am coming to Senator Danforth.

We have other Senators who would like to submit questions for the record. I would like the record to show that.

On that particular point that Senator Rockefeller and yourself were touching on, Mr. Bloch, I am led to believe that of the graduate degrees obtained in the institutions of higher learning in the United States in engineering and science, about half of them are foreign students.

Along this line, your friend Dr. George Kozmetsky came by at the end of last year, and he had been in Japan. As I understand it, the Diet had developed and approved a plan for 19 graduate schools and $19 billion.

Will you look into that and give us a report on it, because they are moving into science and engineering in a heavy way now and they are not going to be sending students here. We are trying to get ours over there. They are trying to get theirs away from us and set up their own institutions. Our edge in universities is the one thing that has kept us alive and maybe in a survivable state, in that we have had this outstanding graduate degree work here in this country. But if we lose that advantage, we really will be in a soup.

I would like you to look into that.

Mr. BLOCH. Well, I will be glad to. These are new numbers. I have never heard these before, and I will gladly look at it.

But let me make a couple of comments which pertain to your observation.

Japan has not had the best university system, education system. They are trying to improve it, and they are going to succeed in improving it, so I am not surprised at their focus.

The CHAIRMAN. This is what they intended. They debated it, and they very quietly approved it, and it is a $19 billion program.

Mr. BLOCH. They have not been known for basic research, but they are changing that also. They are going to focus more on basic research, so we should take seriously that competition coming from Japan in basic research, not just in the marketplace but in basic research. That is why we need to keep our research strong.

The CHAIRMAN. Senator Danforth.

Senator DANFORTH. Thank you, Mr. Chairman.

Mr. Bloch, you in answer to the earlier questions by Senator Hollings, distinguished between education on one hand and what I remember you calling the cutting edge of research on the other hand. You talked about two different missions, and you said, as I recall, that you did not want to give up either of those two missions, that they were both very, very important.

I would like to focus your attention on the cutting edge of research mission as distinguished from educating people. I take it that there are thousands of colleges in the United States that educate students. But I am also led to believe that with respect to very high quality research, the cutting edge of research, that is not likely to be spread about at random throughout the country, but instead, research of a very high quality is more likely to be done at some institutions rather than other institutions.

Mr. BLOCH. Well, let me comment on that. It is not a black and white distinction.

By the way, my comparison was on a slightly different thing, but nevertheless, still to the same point.

I would like to say the following. We have to make sure that we are at the cutting edge of basic research. A lot of that basic research is being done in some of the prestigious universities that have a high concentration of instrumentation and people, primarily people. But on the other hand, I also want to say that there is a lot of good research going on in the other institutions and even in undergraduate colleges, and we should not neglect that.

Senator DANFORTH. Nobody is proposing neglecting that.

Mr. BLOCH. I will give you an example.

Senator DANFORTH. Well, let me just ask you this. Nobody is proposing neglecting anything, but it is more likely, is it not, that very high quality research is going to be done increasingly at the large research centers where, as you said, there are concentrations of scientists, there is a critical mass, and where also there are the buildings, the facilities, the expensive equipment that increasingly is a part of research.

Mr. BLOCH. Well, there is more research going on in those universities than in the others, no doubt about it, but I think we would make a mistake if we washed out the research going on elsewhere.

The example I wanted to give you was, by the way, on superconductivity. The new material developments did not come out of MIT, did not come out of Harvard, did not come out of Berkeley. They

came out of the University of Houston and the University of Alabama, a telling point.

The point I am making is that we need to make sure that we have enough participation in the system. True enough, you know, if you look at MIT and if you look at Berkeley and Cal Tech and so forth, they will always get a larger percent of money, as they should. But on the other hand, we need to make sure that we are bringing the other universities along, in areas where they have excellent departments. You know, the interesting part about Harvard and Berkeley and so forth is that they are good in a lot of areas. That does not mean that another university cannot be very, very good in a very small and narrow area which could be equally important. We are finding that out, and that is why you are seeing our money also flowing into these areas.

If you look at the bulk of the money, no doubt about it, it goes to the universities that you are describing.

Senator DANFORTH. Well, you would not favor a random distribution of funds, would you?

Mr. BLOCH. No, I definitely do not favor a random or an equal distribution. I think it has to be based on the quality.

Senator DANFORTH. Let me ask you, just regardless of the distribution of funds question, regardless of the NSF, is it true that increasingly, high quality research requires not just one or two scientists in a very small lab, but a large number of scientists, a critical mass of people?

Mr. BLOCH. Well, that is why we are proposing a Science and Technology Centers Program, exactly for that reason. There are many disciplines today where the individual researcher is still very, very important, and we should not forget that. But in addition to that you need a more cohesive group effort coming from people who have different views, coming from different disciplines, who can combine their knowledge and also can share equipment, which is becoming very, very expensive.

So we have to augment the individual grant with these center grants to do exactly what you are saying. That is true today in disciplines like chemistry and biology, in which it probably was not true ten years ago.

Senator DANFORTH. In the 1986 tax act, one of the things we did was to place a cap on tax exempt borrowing by nonprofit organizations, by colleges and universities. That cap does not have any effect on the public universities because they have access to tax exempt borrowing because they are state institutions. It does have an effect on private universities, and particularly those which are large research universities that have to scrape up large amounts of money to build the laboratories and to buy expensive equipment.

The President of the University of Texas, a public institution, testified before the Senate Finance Committee that he thought that that was a disastrous idea and that it was going to have a major effect on U.S. research.

Do you have an opinion on whether or not that feature in the 1986 tax act is having an effect on science?

Mr. BLOCH. Well, I am pretty sure it cannot help. It has to dampen any kind of private activity that we are depending on, as I said before, especially in the facilities area. I think it was ill-ad-

vised to put that cap on because it really now enjoins some universities from going to the private sector, and with their support plus some borrowing putting up facilities that we talked about before that are so urgently needed.

Senator DANFORTH. If the government is not going to spend a lot of money on building laboratories, that money has to come from somewhere, right?

Mr. BLOCH. That is correct.

Senator DANFORTH. And if we say that we are going to provide less incentive, disincentive for borrowing for the purpose of laboratories, that really is bound to have a negative effect on the quality of science, right?

Mr. BLOCH. Absolutely. And let me just make a parenthetical comment since you brought up the tax act of last year.

There was another provision in there which I do not think is very helpful, and that is that it taxes graduate fellowships.

Senator DANFORTH. That is correct.

Mr. BLOCH. At a point in time when we do not have enough American citizens going to graduate fellowship programs or in graduate study programs.

Senator DANFORTH. It taxes graduate fellowships, it has an institutional cap on tax exempt borrowing, it also brings gifts of appreciated property under the alternative minimum tax so that if there was a wealthy person who was interested in making a major gift of appreciated assets, including securities, to a university, that person could be caught under the alternative minimum tax.

Mr. BLOCH. Right.

Senator DANFORTH. By making that contribution. That also would be bound to have a negative effect on science, would it not?

Mr. BLOCH. I would think so.

Senator DANFORTH. Thank you very much.

The CHAIRMAN. Well, I think you have emphasized that in the "transition rules committee" that you belong to that they spend more time trying to manufacture new loopholes.

If you put in a bill, I will co-sponsor it with you, because that is terrible.

Senator DANFORTH. It is terrible.

The CHAIRMAN. I have not found out what was in that reform act. I am learning. By 12:00 o'clock midnight tomorrow, I hope I will have learned because I have to go back in a little while and keep filling out those tax forms. But no kidding, you put in a bill, let's co-sponsor it, to get rid of that nonsense.

I mean, there is no reason to put that in a bill.

Do you have any other questions?

Thank you very, very much, Mr. Bloch. You have a superb grasp of the problem, and we appreciate your and Dr. Moore's presence here this morning. We will ask the next panel to come forward while we recess momentarily for this rollcall vote. We will vote and come right back, and please, panel, approach the table and have your seats, please.

[The statement follows:]

TESTIMONY OF

MR. ERICH BLOCH

DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

THURSDAY, APRIL 14, 1988

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I am pleased to have this opportunity to discuss the Foundation's budget request for FY 1989. Education and basic research in science and engineering have a direct, long term relation to national economic well-being. Our budget request highlights the Foundation's potential to contribute to this relationship.

SCIENCE, TECHNOLOGY AND NATIONAL GOALS

I think we can be pleased that recent debates over economic matters have come to focus more strongly on science and technology. Increasingly we understand that we must look to our own educational, research, industrial, and governmental systems to make us competitive. This understanding is only a first step, but it is very important.

Although there is a growing consensus on the need for strengthening our educational and research systems, fiscal problems have so far prevented us from taking the action we would like. I hope this can be the year when that begins to change in a decisive way. It requires a long-term view, and a determination to identify and support national priorities in the difficult environment of fiscal constraint.

The Federal budget request for FY 1989 proposes to address urgent national priorities within the terms of the bipartisan budget agreement. In identifying high-priority areas that must be funded adequately, science and technology are singled out for

their contributions to long-term improvement in national productivity and global competitiveness.

A nation that wishes to lead -- economically, militarily or politically -- must also lead in science and technology. Investments now provide the base for future strength. Increased support for basic research, particularly at universities, will help to generate the new knowledge necessary for continued innovation and will help to assure the future availability of high-quality scientists and engineers.

NSF BUDGET REQUEST

The FY 1989 budget request for the National Science Foundation is $2.05 billion, an increase of more than 19% over FY 1988. It includes a proposed new appropriation for Science and Technology Centers.

Table 1
NSF FY 1989 Request
(dollars in millions)

Research & Related Activities	$1603.0
Science & Technology Centers	150.0
U. S. Antarctic Program	141.0
Science & Engineering Education	156.0
Total	$2050.0

We believe that the request reflects the dynamic forces in today's research as well as the fundamental relationships which underpin the health and vitality of the science and engineering enterprise. It returns to a rate of growth which doubles the Foundation's budget over the next five years. This significant growth is a central feature of the Administration's commitment to science and technology.

The request is formulated around three strategic themes:

- Education and human resources -- because people are our most important asset;
- Disciplinary research and supporting facilities -- because universities are the primary source of new knowledge; and
- Research centers and groups -- because we must foster interdisciplinary investigation and build stronger links between universities and industries to use our technical resources most effectively.

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We must be concerned with breadth, flexibility, and the changing nature of investigation. And we must extend our efforts to find and encourage all scientific and engineering talent.

We have noted a gradual transition in the nature of scientific inquiry in the last decade. Technologies such as satellite communication and large scale computing enable scientists to work with data sets of great size and complexity. These and other tools have opened completely new avenues of experimentation and illustrate the gradual shift to greater interdisciplinary collaboration as well as the increasing need for large-scale facilities and sophisticated instrumentation. Such collaborative centers and large-scale facilities must be assured a stable funding environment if they are to direct their energies to producing high quality science. It is simply not cost-effective to "power-down" productive, large-scale activities simply because of short-term vagaries in the funding cycle.

In this regard, I would point out that once again we have submitted a draft five-year authorization bill. It reflects this Administration's commitment to doubling the Foundation's research budget over the next five years. Moreover, it reflects the realization that long-range planning must be accompanied by long-range commitment. While passage of this bill will not preclude annual revisitation of its provisions by the Congress, it will be an important acknowledgement of the importance of developing a strong scientific base for the long-term scientific, as well as economic health of our country.

PEOPLE: EDUCATION AND HUMAN RESOURCES

A basic tenet of our long-term view is that people must be our highest priority. Trained and educated people are the major resource of any modern society.

We have developed a broadly based approach for support of education and human resources; all parts of the Foundation are engaged in this effort. While the research directorates support much of the effort at undergraduate and advanced levels, the Science and Engineering Education directorate supports precollege as well as some advanced programs.

The actual numbers of scientists and engineers supported -- at all levels from high school through senior scientists -- are rising sharply. Across the Foundation, the FY 1989 increase will support over 14,000 additional people -- a 30% increase over FY 1987. This is indeed a positive development. (Table 2 and Figure 1)

Table 2
National Science Foundation
Support for Human Resources

	FY 1987 Actual	FY 1989 Estimate
Senior Scientists.....	15,800	18,900
Postdoctorals.....	3,400	3,800
Graduate Students.....	14,700	17,100
Undergraduates.....	6,400	9,300
Pre-college Teachers.....	7,200	9,500
High School Students.....	<100	3,000
Total Number Supported...	47,600	61,600

The positive trend of the budget, however, should not obscure the dismal state of science and mathematics education in our schools. Only two weeks ago the Foundation announced the results of a new survey of international science student accomplishments. Once again the United States did not place well. Our 14-year-olds tied for next to last place, while Hungary and Japan took the top places.

With these concerns in mind, our request includes $265 million for education and human resources, up more than 20% over 1988. Activities are designed for all levels of education, academic career initiation, all types of institutions, and all regions of the country.

The Education Pipeline

The Foundation's precollege programs are the largest component of the education and human resources effort. Precollege support has grown rapidly, and will rise again by 20% in FY 1989 to a total of $108 million. On a national scale NSF's role at the beginning of the education pipeline is small in terms of dollars, because our resources are used to stimulate others, to innovate, to lead. The main effort must come from the States, which bear principal responsibility for education.

One mechanism for multiplying the impact of NSF investments is to promote linkages among all concerned sectors. Ongoing projects for materials development involve education developers, publishers and school systems. New projects are planned in FY 1988 and FY 1989 for partnerships between the private sector, local schools, colleges and universities. Over 35 States are represented in proposals currently under review to develop model cooperative precollege education efforts on a local or regional scale.

Undergraduate programs are another area of major emphasis. The Foundation has developed a comprehensive range of programs to address critical needs identified by the National Science Board and other groups. As activities deferred from FY 1988 are initiated or expanded in FY 1989, support will rise to $65 million -- a 62% increase -- for activities for students, faculty, curriculum, instrumentation and laboratory development, and underrepresented groups.

Several distinct programs are included in the Foundation's undergraduate effort. The Research Experiences for Undergraduates (REU) program provides hands-on student participation in research programs. In FY 1989 $17 million is planned for REU, to involve an estimated 5500 undergraduates. The Undergraduate Faculty Enhancement program supports seminars and conferences on recent developments in science and engineering. Additional support, for research by undergraduate faculty, is provided through the Research in Undergraduate Institutions (RUI) program. Together these activities for undergraduate faculty are planned for over $14 million in FY 1989.

The Instrumentation and Laboratory Improvement (ILI) activity provides support for undergraduate instructional instrumentation through the College Science Instrumentation Program for two and four year colleges and through ILI support to PhD institutions -- more than $20 million is planned for FY 1989. The Foundation's undergraduate curriculum development efforts will continue to focus on two areas of special concern: calculus and engineering ($4 million in FY 1989.)

Finally, almost $9 million is planned in FY 1989 for activities to broaden participation. These efforts include Career Access Opportunities for Women, Minorities, and the Disabled (a program for regional centers and prototype activities) and the proposed new Research Careers for Minority Scholars for enrichment programs for promising minority undergraduates.

Recruitment and retention of scientists and engineers is a pressing problem. Almost no science is taught in elementary school, and less than a quarter of high school graduates are qualified to do college-level science or engineering. For every 10,000 high school sophomores, only 20 eventually earn doctorates in natural science or engineering. This is not enough to meet the needs of industry, government, and society as a whole.

In the long run, we hope that efforts at the precollege level will yield greater participation in science and engineering. But we must recognize a more short-term fact: new PhDs for year 2000 are in high school <u>now</u>. We must have strong efforts focussed at the undergraduate level and above. (Figure 2)

Broadened Participation

A large part of any solution to the shortage of human resources must come by increasing the participation of underrepresented groups in science and engineering. The Foundation's investments to broaden participation total almost $49 million in the FY 1989 request, an increase of nearly 30% over FY 1988.

We have made good progress in encouraging women to join the science and engineering community, although we are far from where we should be. We should also be concerned about evidence that the participation rate is leveling off.

The Foundation will continue to focus on this critical issue both through the Career Access program mentioned above, and through its highly successful programs for Visiting Professorships for Women (VPW) and Research Opportunities for Women (ROW). We also are actively involved in the interagency task force on women, minorities and the disabled in science and engineering.

With minorities our programs have not shown the desired change. We have instituted new activities for minority research and resource centers and for minority students which may have an important effect.

These activities are among six Foundation programs focused on minority participation, ranging from institutional and individual support to comprehensive regional centers. Research Improvement in Minority Institutions (RIMI) and Minority Research Centers of Excellence (MRCE) focus on strengthening minority institutions. Research Careers for Minority Scholars (RCMS), Minority Graduate Fellowships (MGF) and Minority Research Initiation (MRI) support undergraduate and graduate students, and new investigators at the beginning of their research careers. The Career Access program supports regional centers designed to increase minority presence in science and engineering. In FY 1989 over $23 million is planned for minority programs.

We are making special efforts in both education and research programs to address this issue. A good example is the South Carolina Cooperative Plan for Professional Development of Science and Mathematics Teachers in Grades 7 - 12. Significant numbers of minority teachers are involved in summer workshops, through a consortium of five universities and colleges. Other institutions in the region are beginning to replicate the activity. State and university resources have been committed to the project.

People work and develop in institutions, which means that we must be sensitive to the need to broaden participation beyond the institutions that already compete well. NSF has sought to do this especially through the Experimental Program to Stimulate

Competitive Research (EPSCoR) program, with encouraging results in thirteen States and territories.

EPSCoR awards feature state, academic and private sector cooperation to assess research strengths and weaknesses, and to design strategies for long-term improvement in the quality of their science and engineering efforts. EPSCoR projects include substantial contributions by participants. The Foundation's $36 million investment in EPSCoR states since 1980 has stimulated almost $100 million from state, academic and industrial partners.

A point that is not well known is that NSF is especially important in the States that receive relatively little Federal R&D support. We provide about 10% of Federal R&D funds going to the bottom 10 states, compared to less than 3% of the total for the top 10 states.

UNIVERSITIES: DISCIPLINARY RESEARCH AND FACILITIES

The second requirement for better economic performance is a stronger university basic research capability. I would hope that 1989 is the year we can move forward in this area.

The Foundation continues to make its largest investments in this area. The FY 1989 request includes more than $1.2 billion for disciplinary research and research facilities, an increase of 8% over FY 1988.

University basic research is more important today than ever before. The world is rapidly shifting to a knowledge-based economy. In our system basic knowledge is produced mainly in universities.

Trends in Support

I want to highlight briefly some trends related to basic research:

- In contrast to education, research support has not been rising in recent years. In constant dollars, the NSF research and related appropriation for 1988 is almost exactly where it was in 1985. (Figure 3)

- Overall, Federal investment in basic research and in civilian R&D has grown slowly in the past few years. By contrast, research investments by our major trading partners continue to advance strongly. We are not matching their effort in civilian R&D. (Figure 4)

We must do better than this. In nearly every field that NSF supports the opportunities to make important advances have outrun the available funds.

Emerging Research Areas

Superconductivity is one of a number of areas in materials research that promises important economic benefits. Funding for research in high temperature superconductivity is projected to increase by over 50 percent between FY 1987 and FY 1989. Although the mechanism responsible for high temperature conductivity is not yet understood, current research efforts are examining the theory of superconductivity and include an initiative to develop superconducting generators, motors and cables.

In mathematics, chaos theory is almost entirely new in just the past few years. It already promises to help us understand complex phenomena that have eluded us in studies ranging from weather patterns and fluid dynamics to distribution of biological resources.

Biotechnology continues to be an area of accelerating development. New knowledge from basic research promises new applications. Recent emphasis on biological communication, how chemical signals operate between cells and between organisms, has significant implications for agriculture and human health. Major new industries -- only dimly visible today -- will stem from today's basic research.

American manufacturing appears to be starting a comeback, as it must if we are to prosper. But manufacturing will change dramatically over the next decade as new materials, computer aided engineering design, robotics and other new technologies emerge from basic research. Studies in neuroengineering are comparing neural networks in the human brain with computer circuitry. Findings will be of direct use in development of robot visual systems, computers that recognize and respond to human speech, and other advances with industrial applications.

Research on global change is focusing on unprecedented studies of the planet Earth as a complex system of interacting processes. We are at the threshold of understanding the far reaching implications of natural and man-induce environmental changes. This undertaking requires not only direct support for research, but large-scale operations and logistics support.

The Antarctic, because of its major influence on world climate, has a unique role in research on global change. Operations support here is critical. Only one research ship with ice strengthened capability, the Polar Duke, is available following the decommissioning of the Coast Guard's Glacier. Current

requirements for 300 days per year for each of two ships cannot be met. The Foundation's FY 1989 request includes provisions for leasing a new ship.

A joint initiative on ocean engineering theory, supported by the Engineering and Geosciences directorates, focusses attention on engineering problems related to deep and coastal ocean environments. This program's goal is to foster technological innovations related to the conservation, development and use of ocean resources.

The world is in an unprecedented period of technological development. We know that nothing like the present has been seen before, and a reasonable guess is that the future will be even more intense and fast-paced.

Science and technology are critical factors in the nation's global stature. Unless the United States is willing to cede its historic position of world leadership to others, we must find resources for the necessary investment in basic research.

LINKAGES: CENTERS AND GROUPS

Cooperation among the various sectors of our economy is the third element of an effective science and technology enterprise. It is encompassed in the third theme of our proposed budget, support for research centers and groups.

This is especially important in the United States because our research system is built on the research university. This keeps research and education tied closely together, which is a major strength and one of the reasons why our universities are the envy of the world.

The drawback of our system is a tendency for university research to be isolated from economic reality. We need explicit mechanisms to make sure this does not happen, and that the results of our laboratories flow smoothly into industry.

NSF has been a leader in developing new ways to bring the various players in science and technology more closely together. In recent years the Foundation has given an increasing number of long-term awards to universities to establish interdisciplinary laboratories and centers. The primary purpose of these awards has been to strengthen our national capability to perform certain types of large-scale research that cannot be performed by single investigators or small teams with limited resources. Additional purposes have been to facilitate interdisciplinary research, to foster university-industry interactions, and to build a stronger knowledge base in certain areas critical to industrial competitiveness or a clear national need.

Support for research centers and groups totals $477 million in the FY 1989 request, an increase of $188 million over FY 1988. The new program for Science and Technology Centers is a significant feature of the proposed increase.

Technology Transfer and Research Centers

The Foundation's Engineering Research Centers (ERCs), established in 1985, have stimulated significant industrial support and thereby brought new resources to the universities. Each NSF dollar has been more than matched by industry contributions. Even more important, however, is the contribution that industry has made by committing time and people to help make the centers work.

While the ERCs currently have the most active involvement with industry, significant connections are also reported by many other types of laboratories and centers, including a majority of the nine Materials Research Laboratories and many of the 39 Industry-University Cooperative Centers.

Transferring of information from NSF centers to industry takes place in a number of forms, including contributions to the scientific and engineering literature, facilities access, meetings and workshops and joint projects between center researchers and small businesses.

The centers concept has also stimulated interagency cooperation, notably the FY 1988 Plant Sciences Centers, jointly supported by NSF and the Departments of Agriculture and Energy.

Science and Technology Centers

Our budget for 1989 requests funding to extend the ERC concept to other areas in science through the Science and Technology Centers (STC) program. The STC program, originally proposed for FY 1988 was not initiated because of severe budget constraints. However, over 300 proposals from 124 institutions in 42 States were received, and merit review is proceeding.

We propose a new appropriation in FY 1989 of $150 million for Science and Technology Centers, sufficient to fully fund 12 to 15 centers for up to five years. Our intention in keeping this appropriation separate and in providing full funding at the outset is to avoid committing the Foundation's future resources to an unwise degree, and to answer the concern of those who fear that the centers might displace traditional support mechanisms.

We understand this concern, but think it is misplaced. The Foundation's support for individuals has been and will continue to be our primary concern. (Figure 5)

I would also note that many individual researchers work in centers or are seeking to establish centers. Among those who have submitted center proposals are 350 currently-active NSF principal investigators.

The traditional organization of research in our universities into disciplinary departments has been tremendously productive. It is still the best single way to do science. But it is not the only way. Research groups crossing disciplinary lines, and interdisciplinary centers tied closely to industry for more effective knowledge transfer, provide healthy diversity. A responsible science and technology policy must balance these approaches.

FACILITIES

The subject of research facilities is an issue which is of concern to both this committee and the scientific community, and I would like to restate here the Foundation's position. As I testified last year, the Federal government does have a role in supporting science and engineering research facilities. Given the Federal role in supporting basic research, it could hardly be otherwise.

NSF's support of facilities is closely linked to basic research. Each NSF program considers competing needs for project support, instrumentation, and research facilities in deciding how to allocate the limited funds available. Highest priority is given to supporting the people who conduct basic research. Thus, we fund facilities when it is clear that progress in the field has a significant dependence on a facility. In practice this means that we support many specialized facilities such as telescopes, oceanographic vessels, and supercomputers, but few facilities of a more general nature.

This policy has served us well. We will continue to carefully assess the competing needs of scientific disciplines in our attempt to fund the most promising lines of research.

SCIENCE AND ENGINEERING PERSONNEL AT NSF

I want to say a word here about NSF -- how we get our work done and the people we need. You know the problems we are having in hiring senior scientists and engineers. Both at universities and in industry, many earn salaries well above the government pay ceiling. To ease some of the strains of the current system, we are proposing an amendment to the NSF Act concerning payment of benefits for rotators.

We are not proposing to exceed the current pay ceiling. We are seeking authority to compensate university or industry people for

extra costs they incur when they come to NSF as rotators. These include travel costs, moving costs or per diem, and the fraction of their insurance and retirement benefits that would otherwise be paid by their home institution. These costs -- incurred as a result of accepting a temporary position with NSF -- should be payable without regard to the limits on direct salary. That is only fair, and is consistent with the Federal ceiling, which applies only to salary, not including insurance, and retirement benefits.

We believe the proposed amendment adheres to the long-term NSF policy of "no loss-no gain" for rotators and will help us to attract rotators.

PRIORITIES

I would like to focus for a moment on responsibilities and priorities.

Within the Foundation there is a constant need to make our programs fit the available resources. We cannot accomplish everything, and we must continuously reassess existing areas of support in order to make resources available for new research directions.

The FY 1989 budget was developed with this in mind. Our first priority is people, both in developing human resources and in research support. We stress the value of the individual investigator, but we also recognize the value of group efforts and centers. We have also made difficult choices between specific disciplinary areas, providing increases for the most important areas at the expense of others.

The Congress has the same problem. You have before you proposals for a number of large projects, some of which are entirely science projects and some which serve other goals as well. Scientists and engineers can tell you why our programs are important, but have no special expertise with respect to other choices.

We do know, however, that nearly all Federal missions -- from highways to health -- depend on scientific and engineering expertise, and will benefit from new knowledge and new technologies. The most important thing is to make sure we have highly trained people, and that we keep our research programs diverse and broadly based. Neither the space station, nor the supercollider, nor the human genome project will be successful without the right people, and all are heavily dependent on new technology.

SUMMARY

The National Science Foundation has put forward a proposed budget for FY 1989 that will make significant progress in strengthening our science and engineering enterprise:

- We focus on people, because everything else depends on that most basic resource.
- We emphasize university basic research, because universities are the core of our research capability.
- We are mindful of balance, among different areas of science and engineering, and among different modes of support, because diversity provides the richest environment for inquiry and innovation.

These themes are at the heart of the Foundation's mission to promote the health of science and engineering research and education. They delineate the Foundation's fundamental contribution to the nation's global leadership.

This committee has played a lead role in building the vital recognition of the links between research, education and the welfare of our nation. I hope we can count on your support for our request.

Figure 1

NATIONAL SCIENCE FOUNDATION
SUPPORT FOR HUMAN RESOURCES

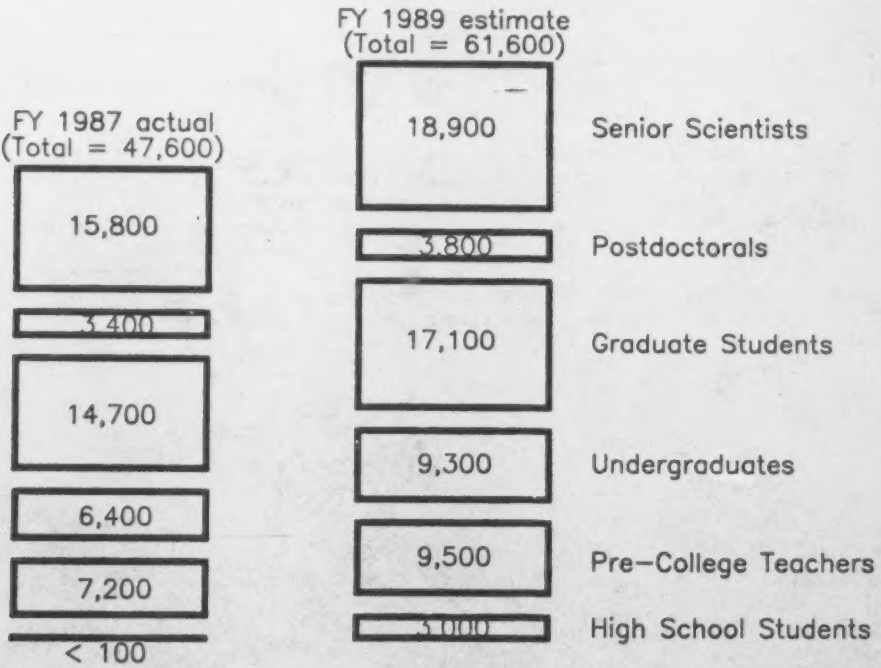


Figure 2

PERSISTENCE OF NATURAL SCIENCE AND ENGINEERING INTEREST FROM HIGH SCHOOL THROUGH PH.D. DEGREE

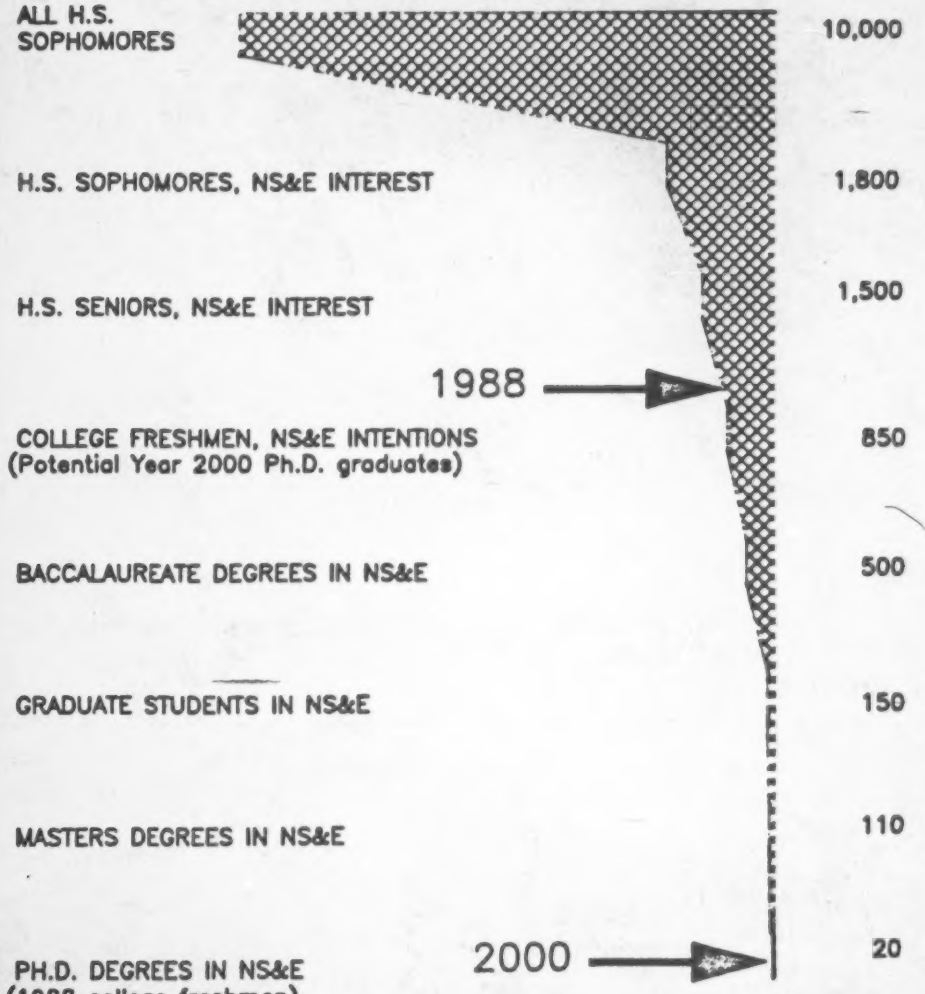


Figure 3

NATIONAL SCIENCE FOUNDATION BUDGET TRENDS RESEARCH AND RELATED ACTIVITIES

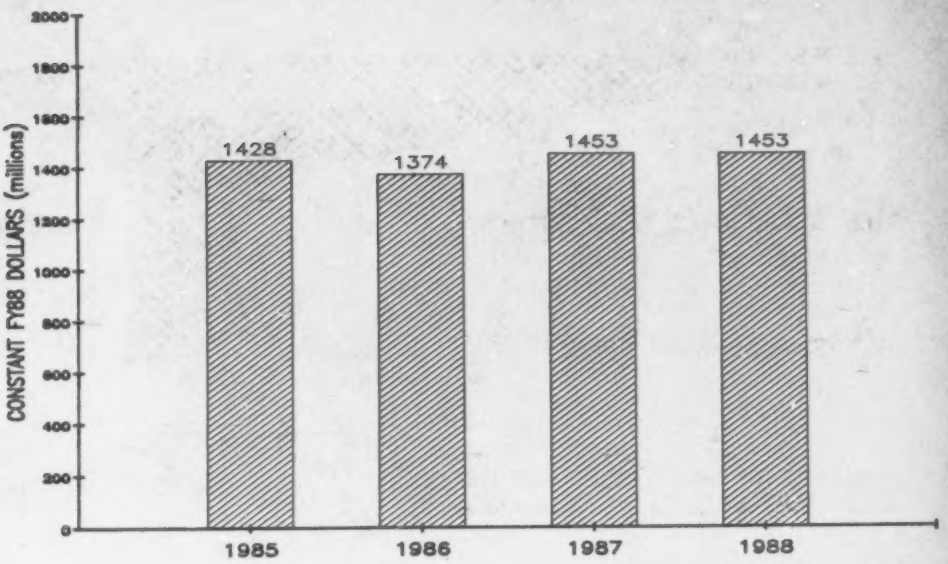
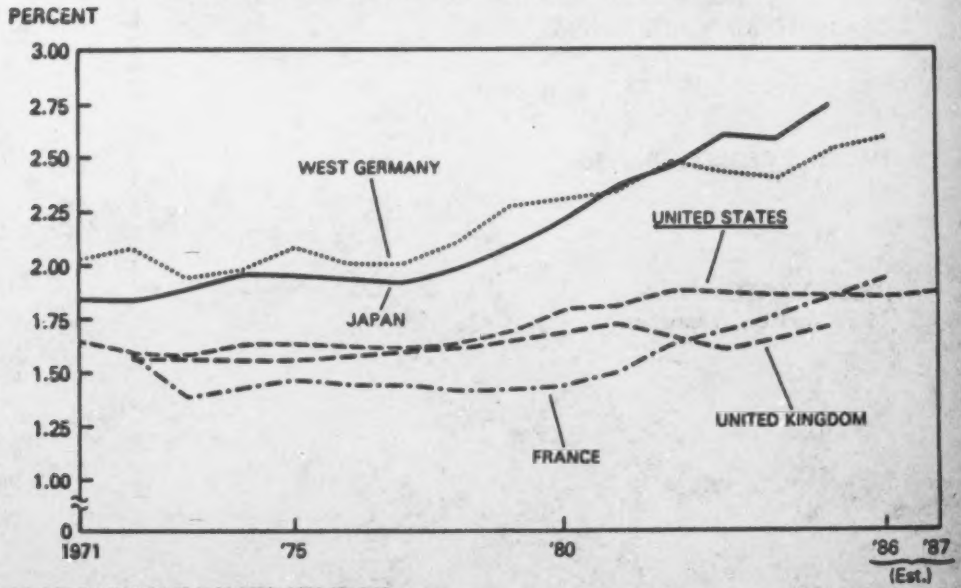


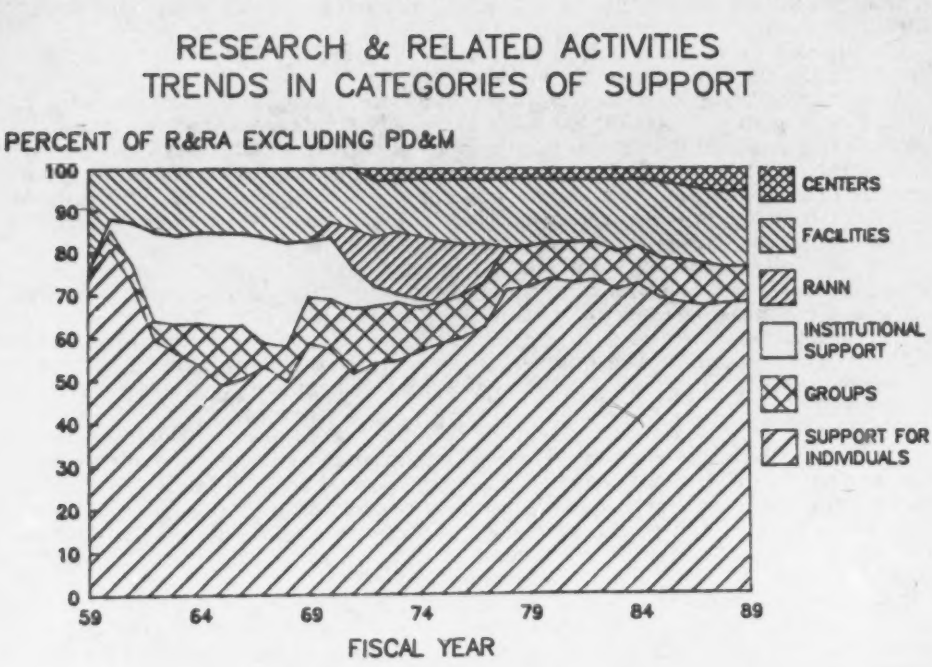
Figure 4

NON-DEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT (GNP) BY COUNTRY



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

Figure 5



QUESTIONS OF THE CHAIRMAN AND THE ANSWERS

Question. Some scientists have expressed concern about the proposed Science and Technology Research Centers. They worry that centers will do little more than insert an additional layer of bureaucracy between NSF and the individual scientists.

How does NSF intend to insure that its Science and Technology Centers Program does not increase the number of administrators at the expense of the researchers? Can NSF ensure that individual grants will not be cut in order to fund centers?

Answer. NSF's Science and Technology Research Centers (STCs) are not intended as substitutes for individual investigator grants. The STC Program has been designed to provide mechanisms for approaching new and different types of problems—problems that require the particular advantages that centers provide: opportunities for multidisciplinary collaboration, shareable facilities and equipment, long-term and stable support. The STCs will not be just another way to "pass" funds to individual investigators, and, therefore, they will not simply be a layer intervening between NSF and individual scientists. And, through the use of cooperative agreements, the numbers of administrators to be hired will be held to the minimum necessary to support the center's goals. Finally, the FY 1989 Budget Request includes a separate appropriation account designed explicitly to make clear just how much support is going to centers and how much to individual investigators.

Question. Although the Science and Technology Research Centers appear as a separate line item in the President's budget, they will be overseen by the same NSF divisions that fund individual grants.

How will establishing a center in a given field affect individual investigators in that field? Will the money for a center in a given field simply be added to the funds available for work in that field, or will there be a corresponding cut in funds available for researchers not affiliated with centers?

Answer. Although the substance of the STC Program is being managed by the NSF divisions and directorates, the Program is being run as a single competition across the entire Foundation. And funds for the Program will be held in a special account, separate from the funds for individual investigator grants. Therefore, STC proposals in, for example, physics, are not competing with physics individual investigators grants; they are competing only with other STC proposals. Therefore, the

budget as requested protects against trade-offs between center support and individual investigator support in given fields.

Question. One of the goals of the EPSCoR program has been to strengthen research capabilities at institutions in states that have previously received relatively little NSF money.

Has there been a significant change in the distiribution of NSF funds in recent years? Or are the rich schools just getting richer?

Answer. Statistically, the distribution of NSF funds among the states and the institutions of higher education has been extremely stable over the past decade. In general this has meant that the larger, more prestigous institutions have received significant support from NSF. Our award distribution has, to a very large extent, mirrored the distribution of scientists and engineers throughout the U.S. However, as I have discussed in other testimony, NSF is the second-most prominent supporter of research in the bottom ten states, surpassed only by USDA.

The EPSCoR program is a long-term educational process, improving the professional capabilities of researchers in those states, improving their physical infrastructure, and encouraging them to remain there in the face of competition from the larger institutions. We are getting more institutions in those states interested in NSF research programs. The number of institutions funded by NSF in the lowest ten states grew by 60% from 1980 to 1987, while that number in the top ten states grew by 50%.

Question. As your testimony indicates, the NSF funds almost 15,000 graduate students in science and engineering. Even though graduate student stipends are small (usually less than $10,000 a year), NSF spends more than $100 million a year supporting graduate students through fellowships and research grants. In 1986, the tax laws were changed and graduate student stipends became taxable. To compensate for this new tax liability, many graduate student stipends have been increased by 10–20%.

How has this change in the tax law affected NSF's funding of graduate students? Have stipends been increased across the board and if so, where is the additional money coming from? Have there been cuts in the number of graduate students funded as a result of the new tax laws?

Answer. NSF's support of graduate students is mainly through two mechanisms: research assistants on NSF grants (approximately 85%) and graduate fellowships (approximately 15%). Research assistant stipends are set by the individual grantee institutions according to their own internal guidelines. Normally cost increments are reflected eventually in increased average grant sizes. NSF has not tracked institutional responses to the Tax Reform Act, but we presume that institutions are making appropriate adjustments. We do not sense that the number of research assistants supported has been adversely affected.

Current NSF funding priorities place a high emphasis on support of graduate students as a key element of our human resources intitiative.

With respect to graduate fellows, the annual stipend was increased in 1987 from $11,100 to $12,300 in order to maintain the after-tax stipend income of fellows. Additional funding for this purpose ws requested by NSF and approved by the Congress in the FY 1987 Budget. The number of fellows was not reduced.

Question. In recent years NSF has substantially increased its undergraduate science and engineering programs. What level of funding for these programs did NSF request in the FY 1989 budget submitted to OMB? What levels of funding are anticipated in the coming years.?

Answer. The NSF request to OMB for undergraduate programs for FY 1989 was $32 million above the FY 1988 request. This request was based on plans for expanded efforts beyond the $68 million proposed for undergraduate activities in the Foundation's FY 1988 budget request to Congress.

The Foundation did not receive its full budget request for FY 1988, and thus the current plan for undergraduate activities in FY 1988 is $40.1 million. The FY 1989 budget request to Congress includes a nearly $25 million increment for undergraduate activities, building on the FY 1988 current plan.

In coming years the Foundation will continue to expand its efforts at the undergraduate level. Initially we look forward to a rapid rate of growth to establish the coordinated set of basic programs planned for students, teachers, curricula, instrumentation and laboratory development, and underrepresented groups. Once a strong set of programs is fully in place to provide a basic framework (with sustained funding in the range of $100–$125 million), we expect undergraduate activities to continue to have high priority and to grow in conjunction with overall Foundation plans for education and research.

Question. Researchers funded by NSF have complained about rapid fluctuations in funding levels over the past few years. Researchers in a given field complain that during one funding cycle only 10% of the proposals reviewed will be funded, while the next cycle 40% will be funded. The resulting uncertainty has caused frustration among the research community.

In your testimony, you've mentioned the need for stable funding for centers. What can NSF do to provide individual researchers with more stable funding levels? What can Congress do?

Answer. Support for individual investigators has been the largest single mode of NSF research support throughout the agency's history. This category of support has shown steady increases in both current and constant dollars. Since 1978, individual investigator support has exceeded 60% of expenditures annually.

Against this background of priority for individual investigator support, it is important to note that emphases in scientific subfields evolve in response to new developments and research opportunities. This is reflected in the Foundation's long range plans and budget requests which, with input from the scientific community, set out critical areas where increased support promises significant advancements. The assurance of stable, significant funding levels for individual investigators shown by the Foundation's expenditures does not, and should not, assure stable funding in all subfields.

The NSF will continue to devote the major share of its research expenditures to individual investigators. Continued support from Congress for growth in the Foundation's research appropriation, and for other major activities that benefit individual investigators, will support this priority.

Question. Another cause of concern among researchers has been the increasing amount of time spent writing and reviewing research grant proposals. Has NSF considered giving more two and three-year research grants in order to reduce both the amount of uncertainty and the amount of paperwork that researchers have to face?

Answer. Determining the appropriate balance between short, medium and long-term research awards is a central and constant concern of the Foundation. NSF uses several different funding arrangements: grants, contracts, cooperative agreements. In general, these range in duration from six months to five years. The most common award instrument is the two or three year continuing grant; one-year awards are in the distinct minority.

While the promise of a relatively stable funding future is cost effective in many regards, making too large a proportion of long-term grants constrains the ability to undertake new starts in promising areas of research. This is particularly true in a period, such as the present, of "flat" appropriations, in which the Foundation's budget has seen no increase in real dollars for three years.

We are sensitive both to the amount of time spent preparing proposals and to the demands the merit review process makes on the reviewer community. Where feasible, such as in NSF's Centers programs and the Presidential Young Investigator awards, for example, grants are made for longer terms.

Question. It's very difficult to determine the economic value of basic research. The return on investment is often not apparent for decades. In your testimony you've mentioned the critical role that science has to play in making America economically competitive.

How does basic research benefit the economy? How long does it take to realize those benefits.

Answer. There is no simple answer to either of these questions. Most fundamentally, basic research benefits the economy because it is the source of new knowledge that can be used to develop new or improved products and processes for the economy. To take a good current example, basic research in superconductivity is now creating materials in the laboratory able to conduct electricity without resistance at temperatures far higher than previously thought possible.

If this research eventually produces materials that superconduct at room temperatures and are usable for manufacturing practical products—a result that we cannot expect soon, but may hope for eventually—the results would be new electrical technologies of incredible importance. Electrical generation and transmission over long distances would be possible without losses. Electric motors would become much smaller and far more efficient, with tremendous savings in energy. Electronics would be revolutionized. Magnetic levitation would make possible efficient high speed trains.

It has taken more than a century for current electrical technology to develop, incorporating many new research findings along the way. In general, the time from discovery of a new phenomenon to widespread practical application has been meas-

ured in decades, in large part because many research advances often have to be combined to develop an important new technology.

There are exceptions to this rule, however. In general the time from discovery to application has declined, and in some disciplines, such as biotechnology, the time between the basic discovery and practical use may be quite short.

As an issue of policy, an important objective should be to reduce this time lag whenever possible. In part that can be done by facilitating the transfer of new information from the laboratories in which it is created to industry. That is why cooperative efforts involving universities and industry, such as the Engineering Research Centers and the Science and Technology Centers of the National Science Foundation are so important.

QUESTIONS OF SENATOR INOUYE AND THE ANSWERS

Question. The National Science Foundation has made a decision to delay the production of the NNTT (National New Technology Telescope), which is to be housed on Mauna Kea, Hawaii. Please provide this Committee with the rationale behind this decision?

Answer. In the past several years NSF has supported, through NOAO, research on the development of technology necessary to build a new generation of telescopes with large mirrors. As a result of this work, NOAO has concluded that the next step is to construct individual eight-meter telescopes before attempting a multiple mirror/common mount telescope.

The National Optical Astronomy Observatories' (NOAO) long-range goal remains the building of the NNTT, a telescope with four 8-meter mirrors on a common mounting sited on Mauna Kea. It will be a major technical challenge to construct 8-meter mirrors that can take advantage of this site. It is also necessary to understand and correct the features of dome and telescope design that cause degradation in image quality.

Accordingly, NOAO now plans to propose to the National Science Foundation the construction and operation of two national facilities with one 8-meter telescope in each hemisphere prior to proposing for an NNTT.

Question. I have noted that the National Science Foundation has continuously received an increase in its annual budget. Yet funding for critical ocean engineering research was cut to approximately $1 million in FY 1988, and this year you are only requesting $1.4 million. What is your agency's rationale behind this decision?

Answer. As reflected in the FY 1989 Budget submission to Congress, no funds were specifically requested for ocean engineering systems research in FY 1988. However, an effort in the broader area of large scale non-linear systems, which is found in the Electrical, Communications, and Systems Engineering division of the Engineering Directorate, is being pursued this year. The amount for this effort in FY 1988 is $500,000.

In FY 1989 the effort will almost be tripled to $1.4 million. Such an increase is significant for any program, and the commitment by the Foundation to this critical area is reflected by the program now being a separate line item in the Engineering Directorate's budget. The Foundation continues to show strong support for this new initiative in ocean engineering systems.

In addition, programs that support ocean engineering are found in the Geosciences Directorate. For example, in FY 1987, appoximately $8.8 million were obligated through these programs, including the Ocean Drilling Program.

Question. In H.J. Res. 395, the Continuing Appropriations Bill for FY88, NSF was urged by Congress to establish an Engineering Research Center within the Pacific Basin that focused on Ocean Systems Research. What have the National Science Foundation and the National Science Board done to date to comply with this intent of Congress?

Answer. The Engineering Research Center (ERC) program suggests general topic areas but does not impose topic priorities or regional preferences on the review process. FY 1988 awards will not be announced until August.

In addition to the ERC program, there are other program areas which might be suitable for ocean systems research proposals. The two most appropriate are the ocean engineering research program referred to in the previous question/response and the Industry/University Cooperative Research Centers program.

QUESTIONS OF SENATOR BENTSEN AND THE ANSWERS

Question. How much is NSF allocating to superconductivity research this year (1988), and how much is budgeted for FY89?

Answer. NSF support for superconductivity research is estimated to be $17.5M in FY 1988 and $20.1M in FY 1989.

Question. Do you agree this is a highly promising field, both for basic scientific research and industrial competitiveness?

Answer. We agree that superconductivity research is a highly promising field. A new generation of computer technology appears to have the most likely near term development success from these new materials.

Question. What information do you have on what other nations are doing in this area of research?

Answer. NSF monitors superconductivity research activities in many other nations. There are many newsletters and reports that provide information in this area. We have also sent program directors overseas to become better informed on the status in other nations, and we also maintain an office in Tokyo.

Question. Is it your impression that others, particularly the Japanese, are quite active in promoting superconductivity research?

Answer. We agree that Japan is one of the leading promoters for research in this area. They have three government agencies mainly responsible for development of high-Tc superconductivity. These are:

Ministry of Education is responsible for research in Japanese Universities. Two of their main projects in this area total approximately $10 million over the next three years.

Science and Technology Agency is mainly responsible for research and development of aerospace technology, and science and technology of materials. They support a Multi-Core Research project on processing and characterization of materials. ($20 million a year) Other major projects will involve funding of an additional $9 million this year.

The MITI program also funds a number of proposals at an estimated level of $20 million a year.

Question. What do you consider NSF's role to be in stimulating superconductivity research, compared to other Federal agencies?

Answer. NSF's role should be in—

1. Training students;
2. Developing new materials;
3. Developing techniques (experimental and theoretical);
4. Providing state-of-the-art facilities—high magnetic fields; and synchrotron radiation sources; high resolution electron microscopy; supercomputer centers;
5. Long term support of the infrastructure that could be turned on to this area of research in a very short time.

Question. Some private companies have already joined to support research in this area—such as the Texas Center for Superconductivity at the University of Houston, which has already raised $27 million from industrial investors. Does NSF give special consideration to research proposals which have also attracted private sector support?

Answer. The paramount criterion for support from NSF remains scientific excellence. However, NSF is interested in leveraging its funds with support from the private sector.

The CHAIRMAN. Our next panel of witnesses is on academic research and equipment—I do not want to use the word "facilities," because you have not had a very encouraging word so far on facilities, but at least we want to provide equipment and support over the entire nation, emphasizing four-year undergraduate activities as well as minority institutions.

We have Dr. Albert E. Smith, the President of South Carolina State College in Orangeburg; Mr. Benno C. Schmidt, Jr., President of Yale University; Dr. Mary Maples Dunn, the President of Smith College; Dr. Thomas P. Courtice, President of West Virginia Wesleyan; and Dr. James J. Brophy, Vice President for Research, University of Utah.

I am going to ask that we start off with Dr. Smith here of South Carolina State. As Senator Rockefeller will be back momentarily, perhaps it is best to have you, Dr. Courtice, testify last, and hopefully Jay will be back by that time.

We welcome each of you, and we will hear now from Dr. Smith.

Incidentally, I will put the full statement of all the witnesses in the record, and you can highlight it if you wish.

STATEMENT OF DR. ALBERT E. SMITH, PRESIDENT, SOUTH CAROLINA STATE COLLEGE

Dr. SMITH. Thank you, sir, Mr. Chairman and Members of the Committee. I am Albert E. Smith, President of South Carolina State College, a historically black college, and an 1890 land grant institution.

I am delighted to have the opportunity to share with you my views on the expanding research activity and related facility needs of historically black colleges. However, before proceeding with my testimony, I would like to thank you, Mr. Chairman, and Members of the committee for the time and effort you are giving to examining the need for academic research facilities. We applaud and appreciate your leadership.

Now, to address the issue at hand, because we live in a highly competitive and complex global society, it is absolutely essential to the welfare and security of this country that we exhaust all avenues in our effort to find solutions to the many pressing scientific, social and financial problems that confront our nation. One avenue that is available and must be fully utilized in this process is our more than 100 historically black colleges and universities.

Annually, these institutions confer 40 percent of the undergraduate degrees awarded to black students in this country. Additionally, 87 percent of the black students who ultimately received Ph.D.'s in the natural sciences are products of these historically black colleges and universities. Thus, these institutions play a strategic role in educating our future leadership in the area of scientific research.

As we move toward the Twenty-First Century, for the first time our nation, the United States of America, finds its position as the acknowledged leader of the world, in question. Heretofore, this country has occupied the unique and distinct position of being the leader of the free world in trade, manufacturing, product development, space exploration, and every other meaningful index of measurement. This position of leadership has been nurtured and sustained through the unparalleled advances in science and engineering that have been made by our nation's cadre of outstanding scientists. Consequently, and more specifically, the driving force behind our advancement in science and engineering has been our nation's colleges and universities.

I believe that we can all agree that this nation's institutions of higher learning have trained the world's greatest scientists, economists, doctors, engineers and others, and in all candor, a significantly large number of foreign professionals as well.

Now, this has been accomplished on the campuses of our colleges and universities in facilities that at one time contained some of the

foremost equipment and instrumentation to be found in the world. Unfortunately, this is no longer the case. To the detriment of this country, the aging of scientific and engineering facilities has led to a decline in research productivity.

Previous testimony before Congress by some of my colleagues from the higher education community has more than adequately pointed out the crisis that exists. Nowhere is this more graphically illustrated than at black colleges and universities and other minority institutions. For the most part, facilities on these campuses, while never on an equal par with those of majority institutions, are presently severely antiquated and grossly lacking in modern equipment and instrumentation needed to do high quality research.

For example, take the institution that I represent, South Carolina State College, a small, historically black state supported institution with an enrollment of 4,200 students. Problems related to facility and equipment limitations are a major, ongoing issue. The Department of Natural Sciences and the School of Engineering Technology at South Carolina State College are currently operating in buildings that were constructed in 1928 and 1940, respectively. Major renovations and/or additions to these facilities have not occurred since 1969. It is estimated that funds needed to bring these facilities up to appropriate standards could conservatively exceed $5,000,000.

Nevertheless, in spite of these and other limitations, we at South Carolina State College are currently exerting every effort to expand our research capability and service to the greater community through mutually beneficial partnerships involving private industry, local, state and Federal agencies. Through this program, South Carolina State College will serve as the research hub and coordinating agency for science and engineering related needs of corporations and governmental agencies located in the tricounty area of Orangeburg, Bamberg and Calhoun counties. The threefold objective of this program is to assist in enhancing economic development throughout the area, help increase the level of productivity of participating corporations and governmental agencies, and strengthen the overall academic program and stature of South Carolina State College.

Mr. Chairman and Members of the committee, we at South Carolina State College, like our fellow historically black colleges and universities all across this great land, are optimistic about our future involvement in this nation's research and development enterprise. We believe that over the years we have more than proven our collective value to this great country through the thousands of young black Americans that we have educated and motivated to assume meaningful roles in our society.

All that we are requesting is an equal opportunity to be a full partner and participant in our country's efforts to regain and maintain world leadership and unquestionable superiority in science and technology.

Now, to help enable this to become a reality, I am making the following recommendations relative to the University Research Facilities Revitalization Program of the National Science Foundation: one, that a long term sustaining level of support for the revitalization and upgrading of academic research facilities at historically

black colleges and universities and other minority institutions be a provision of the mandate to the National Science Foundation; two, that provisions be established to ensure an equitable distribution of funds to a wide range of colleges and universities, and that a fixed set-aside of 20 percent be provided for historically black colleges and universities and other minority institutions; three, that because of severe budgetary limitations and the absence of sufficient private sector support, the historically black colleges and universities and other minority institutions be exempt from the proposed 50 percent matching requirement, or that the amount that these institutions are required to contribute through the formula be reduced to one-third; four, that provisions be established to ensure that peers from historically black colleges and universities and other minority institutions serve on National Science Foundation peer review panels; and five, that a provision be established to provide for an undergraduate research components with specific allocations as a part of the facilities program.

In closing, I strongly recommend that this committee and the Congress take care to ensure that any new facilities program at the National Science Foundation will not simply continue the practice of concentrating resources at a few large institutions, primarily graduate education centers. It stands to reason that this nation would benefit most from a broad-based facilities program that increases the research capability and raises the scientific educational training level of a wide range of colleges and universities.

This country must make use of all of its gifted young men and women.

Mr. Chairman and members of the committee, America must never allow the acquisition of an education to become a luxury that is financially affordable by only a privileged few.

Thank you, and this concludes my testimony.

[The attachment follows:]

ATTACHMENT A

The Research Facilities Revitalization Section of the authorized appropriations for the National Science Foundation (S.1632) for Fiscal Years 1989 through 1992 has the following support levels:

Fiscal year:	*Amount*
1989	$45,000,000
1990	95,000,000
1991–92: Such sums as may be necessary.	

Of the above amounts, 85 percent (38.25 million and 80.75 million, respectively) is designated for major universities or so-called first tier institutions (MIT, Yale, Stanford, etc.). The remaining 15 percent (6.75 million and 14.25 million, respectively) is designated for institutions receiving less than $10,000,000 in total federal funds for research and development in each of the two preceding fiscal years. These are classified as the second tier institutions. Of the 15 percent, 10 percent is reserved for institutions that serve a substantial number of minority and disadvantaged undergraduate and graduate students. This translates into 1.5 percent of the $45,000,000 and $95,000,000 for Fiscal Years 1989 and 1990. More specifically, this amounts to $675,000 in Fiscal Year 1989 and $1,425,000 in Fiscal Year 1990 for *all* historically Black colleges and universities and other minority institutions. This is absolutely no money when we consider the facility revitalization needs at the 100 or more historically Black colleges and universities and other minority institutions.

Now, considering the fact that the National Science Foundation views this as a 50 percent matching program, the $675,000 and $1,425,000 are seen by the National Science Foundation as a $1,350,000 and $2,850,000 program for the historically

Black colleges and universities and other minority institutions. In all reality, this is still an alarmingly small amount of money when we consider the severe need and large number of institutions.

A more equitable distribution of available funds for facility revitalization might be as follows:

A. Sixty percent for major research universities—$27,000,000 and $57,000,000, respectively, in Fiscal Years 1989 and 1990

B. Twenty-five percent for second tier institutions—$11,250,000 and $23,750,000, respectively, in Fiscal Years 1989 and 1990

C. Fifteen percent for all remaining historically Black colleges and universities and other minority institutions—$6,750,000 and $14,250,000, respectively, for Fiscal Years 1989 and 1990. The logic here is that since historically Black colleges and universities and other minority institutions do not have the research infrastructure that even the second tier institutions have to support research and development, a larger percentage of the total dollars for facilities modernization should go to them if the program is to have any impact at all.

In addition to the aforementioned recommendations, it is suggested that the matching requirements be modified to reflect the following:

1. For major universities; one-third federal and two-thirds institutional.
2. For second tier universities; one-half federal and one-half institutional.
3. For historically Black colleges and universities and other minority institutions; no matching requirement. However, if a matching requirement is an absolute must, the suggestion is two-thirds federal and one-third institutional.

The CHAIRMAN. Very good, Doctor.

Mr. Schmidt and the others, may I suggest that you do try to highlight? I am looking at that clock, and I know of another rollcall that is going to take place at any moment, and I do not want to miss your testimony.

So if you would get that microphone, Mr. Schmidt, we would be happy to hear from you.

STATEMENT OF BENNO C. SCHMIDT, JR., PRESIDENT, YALE UNIVERSITY

Mr. SCHMIDT. Thank you, Mr. Chairman, Members of the committee. I am Benno Schmidt, President of Yale University. I appreciate the invitation which this committee has extended to me to discuss the state of research facilities at Yale and other universities. In particular, I want to applaud the efforts of Senator Dodd who, in the University Research Facilities Revitalization Act, has made a most significant proposal to address our critical national need for research facilities.

Senator Dodd's proposal has been endorsed by the membership of the Association of American Universities, for which I am speaking today.

The protection and enhancement of our science research infrastructure is essential not only to the ongoing conduct of research but also to the base of knowledge that is available for commercial development and the quality of academic training in this country. The benefits of this research of course, extend beyond specific scientific discoveries. Fundamental research—inquiry into the most basic questions concerning human nature and the physical world in which we live—not only affects the laboratory and the economy, but ultimately influences the whole spectrum of cultural and intellectual activity.

It is inconceivable to me that our nation could fail to meet the challenge of committing the necessary resources to continue path-breaking inquiry into the most basic questions of life and nature.

Senator Dodd's proposal merits the enthusiastic support of all colleges and universities, and the industrial scientific sector as well.

Since the earliest years of the modern research partnership launched by the creation of the NSF, the Federal government has recognized a need to support construction of research facilities as well as to support the work to be conducted within them. Indeed, between 1960 and 1972, the NSF initiated and carried out two major programs for institutional facilities construction and renovation. Support, however, for scientific research facilities withered in the 1970s, and overall, direct Federal funding for construction of research facilities has fallen by 95 percent in constant dollars since that time.

We cannot count on private philanthropy at Yale or other independent institutions to meet the need for renovating and rebuilding our scientific research facilities. The Tax Reform Act of 1986 has threatened charitable giving both by reducing tax rates and by taxing gifts of appreciated property. At the same time, the $150 million limit on tax exempt debt which private universities may issue has closed off this avenue for financing facilities for 20 of the nation's leading research universities.

Where do these developments leave us? At the national level, they leave us with a massive cumulative deficit in our scientific research facilities. A number of studies have documented the extent and implications of this problem. Dr. Erich Bloch, whom you have just heard this morning, has recently observed that modernizing university research equipment to an acceptable level will require approximately $4 billion, and some estimates run as high as $10 billion.

The White House Science Council's Panel on the Health of U.S. Colleges and Universities, under the leadership of David Packard and Yale physics professor Allen Bromley, concluded in its 1986 report that our universities today simply cannot discharge their national responsibilities in research and education without substantially increased Federal support for facilities.

That panel recommended as one part of a comprehensive research facilities investment policy that a research facilities fund be established within the National Science Foundation for ten years, funded at $500 million a year.

The problems these reports describe seem abstract, but I can illustrate them on my own campus with numerous urgent examples. At Yale, for example, we are faced with two cycles of aging and renewal that are affecting our capital base in the experimental sciences. We see at Yale a major degree of decay in our physical plant, and obsolescence in our laboratories. Over 90 percent of Yale's scientific facilities are more than two decades old; more than half of our scientific facilities are over 50 years old.

We face the need to rebuild these facilities at a time when the capital requirements of safety have increased greatly. At Yale, we estimate that only about 10 percent of our scientific space does not require major rehabilitation at this time.

How do these needs translate into dollars? At Yale we estimate the requirements for rebuilding our facilities to be in excess of $130 million, and we estimate that we will be able to afford from tradi-

tional sources of income and capital expenditure less than one-third of this amount.

Our scientific facilities are at a crisis point, and Yale and other institutions like Yale cannot meet our national responsibilities to continue pathbreaking research without a comprehensive Federal strategy to rebuild our nation's scientific research facilities.

Therefore, speaking for Yale and for the Association of American Universities, I strongly support Senator Dodd's initiative. I also support two features of Senator Dodd's program that would recognize the special needs of emerging institutions to compete for funds and that would further recognize the special needs of historically minority institutions to compete for funds.

I also support a matching requirement for Federal research facilities investments. I believe that a matching requirement will be an effective way for the Federal government to leverage its dollars into the most effective possible result.

Mr. Chairman, I heard your doubts about whether our nation should invest in scientific facilities as well as invest in human resources and equipment needs of our scientific research program. I would only say that from my perspective at Yale—and I believe this is true of other research universities as well—that we cannot proceed with our development of human resources or with our efforts to upgrade our equipment and instrumentation unless we have the basic facilities within which our people and our equipment can do their work. Our facilities at Yale and at research universities across the country are in a sad state of dilapidation at the present time.

Thank you, Mr. Chairman. I will be glad to try to answer any questions that you or the other Members may have.

[The statement follows:]

STATEMENT OF BENNO C. SCHMIDT, JR., PRESIDENT, YALE UNIVERSITY, ON BEHALF OF THE ASSOCIATION OF AMERICAN UNIVERSITIES

Mr. Chairman and Members of the Committee:

I am Benno C. Schmidt, Jr., President of Yale University. I greatly appreciate the invitation which this Committee has extended to me to discuss the state of science research facilities at Yale and other research universities and to offer my assessment and my assistance as you and your colleagues deal with this situation. In particular, I want to applaud the efforts of Senator Dodd, who has made a most significant proposal to begin addressing our national need for research facilities in the form of a proposed amendment to the NSF reauthorization which is captioned as the "University Research Facilities Revitalization Act."

Senator Dodd's proposal deserves the support of the entire academic research community. This proposal has been endorsed by the membership of the Association of American Universities for whom I am speaking today, comprising fifty-six executive officers of leading research universities, both public and private. It has also been endorsed by the National Association of State Universities and Land-Grant Colleges, the Council of Graduate Schools, and the Association of Graduate Schools, which together represent most of the research universities which carry out the competitively awarded academic research programs supported by the National Science Foundation and by the mission agencies supporting research. The enactment of such a graduate research facilities authority together with a companion authority to support undergraduate science, has the broad support of the entire higher education community, including the American Association of Community and Junior Colleges, the American Association of State Colleges and Universities, the American Council on Education and the National Association of Independent Colleges and Universities.

The need to protect our basic science research infrastructure is absolutely fundamental, not only to the conduct of research, but also to the quality of academic training available to students in this country and to the intellectual climate in which our open society flourishes. Thus, I believe that such new companion authorities merit the enthusiastic support of all colleges and universities and the industrial scientific sector as well. Indeed, it has been said that fundamental research affects the whole intellectual life of a society by determining its outlook and the standards by which actions and thoughts are judged. It is inconceivable to me that a truly open society could fail to accept the challenge of committing resources necessary to continue inquiry into the most basic questions of life and nature.

If any additional incentive is needed to reinvigorate this effort, it surely can be found in the growing commitment to research by other nations. For 15 years, U.S. investment in civilian R&D as a percentage of GNP has lagged far behind that of West Germany and Japan, and the difference is growing. France has now passed the the U.S. in this measure of commitment. (Figure 1)

U.S. Trails West Germany, Japan, and France in Non-Defense R&D Expenditures as a Percent of GNP

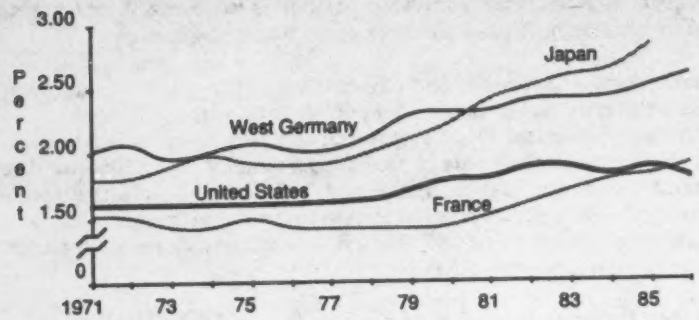


Figure 1

Not surprisingly, then, we find that almost half of U.S. patents, many in key technologies, are now awarded to foreign citizens. The percentage of U.S. patents granted to residents of foreign countries has increased from 19 percent in 1963 to 45 percent in 1986. (Figure 2)

A Measure of a Decline in U.S. Inventiveness and Competitiveness: Percentage of U.S. Patents Granted to Residents of Foreign Countries: 1963-1986

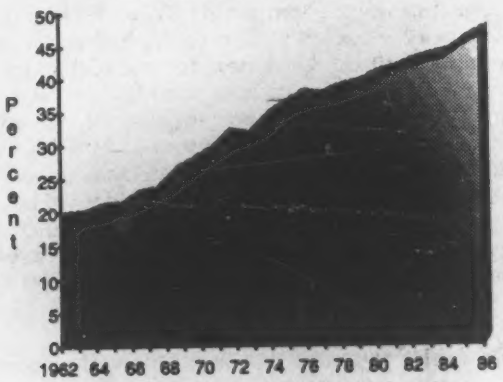


Figure 2

As these figures indicate, although the U.S. scientific and engineering effort remains strong, we can no longer take our preeminence for granted. Today our research and education establishments are subject to unprecedented international competition and severe internal stresses. Our leadership position is jeopardized by weakened commitments to investment in key fields of science and engineering.

A key to reestablishing U.S. science and engineering as preeminent in the world is the renewal of university facilities. This cannot be done without federal government initiative. Senator Dodd's proposal is a part of this initiative which complements similar proposals made in the House, notably H.R. 1905 introduced by Chairman Roe of the House Science, Space, and Technology Committee and other House members. It also builds upon the important initiative pending in the proposed conference agreement on the Trade Bill to establish a research facilities program in the National Science Foundation.

Let me begin then by briefly touching on the nature of federal government support for basic research in academia. I will then describe the problems that institutions are confronting in providing adequate facilities for basic research with particular reference to the situation at Yale with which I am most familiar, and which I believe is typical of the research universities and many colleges as well. I will conclude with some observations on what specifically must be done to rebuild the infrastructure upon which our ability to conduct state-of-the-art basic science research depends.

Following the close of World War II, the influential report submitted to President Truman by Dr. Vannevar Bush, the Director of the wartime Office of Scientific Research and Development, Science – The Endless Frontier (1945), articulated the key principles upon which the federal government's critical role in support of scientific research for four decades has been based. Dr. Bush observed – and time has only proved how correctly – that scientific progress had undergirded the health, defense and prosperity of the nation. Since these are essential and proper concerns of the government, scientific progress must be of vital interest to the government as well. Tracing the history of government support for scientific research back to the early 19th century, Dr. Bush argued that new frontiers in America, whether physical or scientific, historically and for good reason have been made accessible for development by all citizens. Because of the inherent riskiness of basic research and the multiplicity of its potential uses, Dr. Bush recognized that "there are areas of science in which the public interest is acute but which are likely to be cultivated inadequately if left without more support than will come from private sources." (p.12). That support must come from the government.

I would only add to Dr. Bush's argument this observation: The benefits of fundamental research extend beyond specific scientific discoveries. Fundamental scientific research – that is, inquiry into the most basic questions concerning our human nature and the physical world in which we live – creates the intellectual climate in which our modern civilization flourishes. It affects not only the

laboratory and the factory, but ultimately influences the whole spectrum of cultural activity. Inquiry into the origin of the universe, probing into the mysteries of DNA, investigation into the delicate balance between matter and energy, all affect profoundly the way we view ourselves and our possibilities as individuals and as a species. To consciously fail to inquire into these matters is to deny the basic curiosity which characterizes humankind. And so the commitment to pursue these basic questions, much like the commitment to more concrete tasks, such as mapping the human genome or cleaning up our rivers, defines who we are even before the results of the venture are achieved.

The National Science Foundation was created in 1950, five years after publication of Dr. Bush's report, and its establishment reflected the vision of that report. In the years following, the Congress, the NSF and the major funding agencies of the federal government created the world's preeminent research and education enterprise. While the federal government provided financial support for projects, the universities supplied the environment and the trained personnel that made this effort both possible and successful. To borrow terminology from a different context, if the NSF and other federal agencies were the demand side of the equation, the universities of this country were the supply side, and only in partnership could the enterprise go forward. Were it not for the pool of facilities and research talent already at hand, it is difficult to imagine how many years it would have taken for federal expenditures in this area to have produced any worthwhile results.

From the earliest years of the modern research partnership, the federal government recognized the need for support in construction of research facilities, as well as for funding programs to be conducted within them. The 1945 Report of the Committee on Science and Public Welfare, chaired by Dr. Isaiah Bowman, President of John Hopkins University, and published along with the Bush Report, recognized that plans for research in educational institutions would require substantial sums both for facilities and laboratory equipment, and advocated that the federal government provide aid for those purposes.

Between 1960 and 1972, the NSF initiated and carried out two major programs for institutional facilities construction and renovation. The first of these was called the Graduate Research Laboratory Development Program, later redesignated as the Graduate Science Facilities Program ("GSF"). Initially, because of budget limitations, the program emphasized renovation instead of new construction. Later, as funding increased, more money was used for new construction projects. The GSF received a $2 million budget in FY 1960. Participating universities contributed 50% in matching funds to be eligible, and the program was restricted to universities that offered doctoral work in science and engineering and to laboratories that conducted basic research. In FY 1962, the GSF program was expanded to include institutions offering the master's degree as their highest degree, and the institution was permitted to spend up to 10% of the grant money for general-purpose laboratory equipment. In FY 1963, an NSF report stated, "86 percent of the grant money was

used for new construction. . . ." In FY 1964, funding peaked at $30.5 million. It gradually declined thereafter to $4.0 million by FY 1970 when the program was terminated. During the 11-year term of the GSF program, $188.2 million in grants was awarded.

Initiated in 1964, the Science Development Grants (Centers of Excellence) was established to increase the number of institutions of recognized excellence in research and research education in the sciences. That program continued through FY 1972, providing funding for the building and renovation of university laboratories. Universities received block grants awarded on a competitive basis. The potential to develop research excellence was used as a primary criterion for the award rather than the traditional criterion of existing research excellence. Of the $233 million that was awarded to universities under this program between 1964 and 1972, only 16% or $37 million was spent for facilities.

The NSF currently entertains special requests for assistance in construction of specialized facilities required in order to accomplish specific research or education. However, the NSF has no organized program available to support the rehabilitation or construction of research facilities.

Support for science research facilities by other federal agencies has followed a pattern similar to that of the NSF. The Higher Education Facilities Act of 1963 first authorized support from the Department of Health, Education and Welfare for the construction of academic facilities on a matching basis. Authorization for construction grant support was transferred in 1972 to Title VII of the Higher Education Act of 1965. However, appropriations for this purpose disappeared in 1973 after a total of $1,829 million had been awarded for undergraduate facilities and $238 million for graduate academic facilities under Title VII programs. Similarly, funding by NIH for extramural health-related research facilities under the Health Research Facilities Act of 1956 ended in 1972 with a total funding effort of $535 million. Although separate programs for the support of extramural facilities continue to be operated through three of the Institutes, the total appropriation for these programs in FY '85 was $12.1 million and funding was similarly limited in succeeding fiscal years.

Investment in Research Facilities Declines

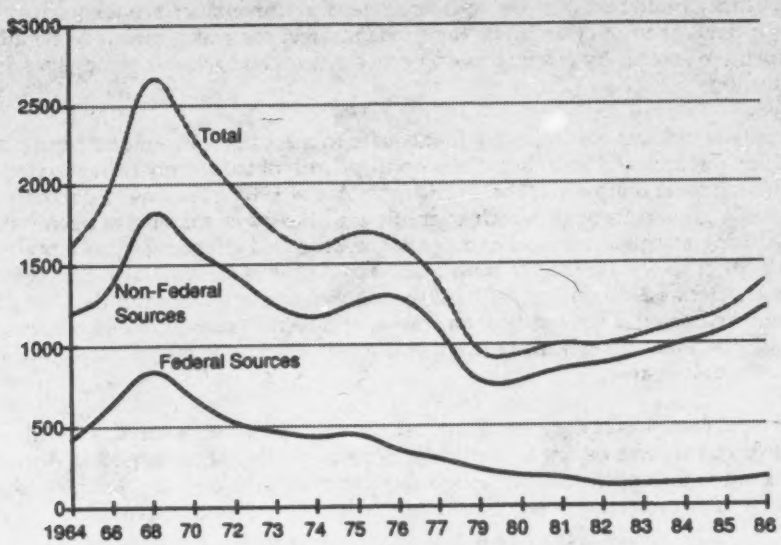


Figure 3

Overall, direct funding by the federal government for research facilities has fallen by 95% in constant dollars since the early seventies. (Figure 3) To be sure, indirect funding for facilities has remained available under the use allowance and depreciation provisions of federal cost reimbursement regulations pertaining to grants and contracts. But this cost recovery is naturally backward-looking, insecure and inadequate. Quite aside from the unrealistically short useful lives assigned for certain categories of equipment and facilities, this system is intended to allow the institution over time to recover yesterday's cost of performing yesterday's scientific investigation. Inflation has obviously increased the cost of replacing facilities above their historic cost, and technological change has increased the demands on and consequent cost of facilities. The simple fact is that because of newly established safety and health standards and regulations, because of the increased precision of scientific measurement and required control of environment and other variables, and because of the changing focus and technology of the science itself, the cost of performing today's experiment – including the portion of that cost representing use of research plant and instruments – has increased tremendously. In addition, yesterday's and today's facilities and instruments in some cases simply cannot be used to perform tomorrow's investigations and experiments. Even if the cost reimbursement regulations were adequate in theory, the Department of Health and

Human Services and the Office of Management and Budget operate under the pressure of year-to-year budget constraints which create a powerful incentive to set an arbitrary ceiling on our cost recovery rate, and universities are themselves faced with incentives to underestimate their true indirect costs as a means of winning competitive awards by offering to do needed research at a lower "cost" than other institutions.

Not only is indirect cost recovery inadequate to meet our current and future capital need for research facilities, but neither will private philanthropy or tax exempt borrowing meet that need. The Tax Reform Act of 1986 threatens to dampen charitable giving, through which scientific facilities have sometimes been funded, by reducing marginal tax rates and treating appreciated gift property as a preference item subject to the alternative minimum tax. At the same time, the Tax Reform Act of 1986 places a $150 million limit on the amount of the tax exempt debt which private colleges and universities may issue, and has effectively closed off that avenue for financing facilities for approximately twenty of the nation's leading research universities.

So, where does this history leave us? At the national level, it leaves us with a massive cumulative deficit in facilities. Several studies have helped to document the extent and implications of the research facilities problem. Dr. Erich Bloch, Director of the National Science Foundation, has very recently stated:

> To modernize university research equipment to an acceptable level will require approximately four billion dollars, and some estimates run as high as ten billion dollars. Total national spending on academic research equipment and instrumentation, which declined 78% in constant dollars from 1966 to 1983, is now at about one billion dollars per year.

There have been numerous studies attempting to estimate the cost impact of deferred maintenance and modernization of university research laboratories and facilities. Harvey Kaiser, in his 1984 study for the Governing Boards of American academic institutions, entitled Crumbling Academe, estimated forty billion dollars. Representative Don Fuqua, former Chairman of the House Science, Space and Technology Committee, in 1985 estimated a minimum of ten billion dollars.

The National Science Foundation's 1986 report on the initial results of a continuing biannual series of studies requested by the Congress also indicates that the problem is serious and extensive nationally. The findings of that report, based only on two quick-response surveys of deans and research administrators, include the following:

- Forty-two percent of the research facilities of the institutions that perform approximately 70 percent of federally sponsored academic

research and development are in poor or fair condition. From this it can be estimated that about 30 percent of total federally supported academic science programs, costing about $2 billion, are inadequately housed.

- In eight of nine fields of science and engineering surveyed, more than half of existing facilities are in fair or poor condition. In addition to the needed modernization of existing space, there are pressing needs for additional space. Ninety-five percent of research administrators responding reported critical needs on their campuses for additional space. Their responses, by field, indicated the following

Additional Space	Facilities Rated "Fair or Poor"	"Most Critical Need"
Engineering	66%	58%
Physical Sciences	62%	61%
Environmental Sciences	67%	73%
Mathematical Sciences	51%	54%
Computer Sciences	70%	55%
Life Sciences	67%	51%
Medical Sciences	80%	36%
Psychology	50%	50%
Social Sciences	67%	59%

- Over half (56.8 percent) of the facilities reported on in the survey were built or renovated before 1970; in the top fifty universities that fraction is almost two-thirds.

- One quarter (26.5 percent) of all facilities were built or renovated before 1960.

The NSF report generally affirms the findings of earlier surveys concerning the consequences of facilities deficiencies. The number and type of research projects which can be undertaken by research faculty are limited across almost all of the major fields of science and engineering surveyed with resulting adverse consequences for the pace and direction of the research itself, for the quality of advanced education programs and for universities, industry and government–the consumers of the products of our research and education programs.

The NSF report also affirms the findings of a 1981 AAU survey which found that obsolete research laboratories compromise the quality of university research and education programs. Within the university, the scope, pace and accuracy of research often are diminished. Advanced education programs are at risk of losing their

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place on the cutting edge in both quality and productivity, promising lines of investigation are foreclosed, and efficiency is sacrificed and competitiveness diminished. Compliance with health and safety regulations is made more difficult and more costly. Modern analytical equipment increasingly requires specialized environments unavailable in obsolete laboratories. Efforts to recruit the best researchers and graduate students become enormously more difficult when candidates are offered only obsolete working environments in which to work and are challenged to build world-class research programs in them.

Our industrial competitiveness is compromised by the effects of an outdated university research and education environment, by the slowed pace of university research, the resulting diminished knowledge base and the inability to train students to desirable levels. Government, like industry, faces immediate adverse consequences which compromise the ability of agencies to fulfill their missions. A weakened knowledge base and diminished capacity for scientific and technological leadership erode governmental functions essential to our economic vitality and our national defense.

The White House Science Council's Panel on the Health of U.S. Colleges and Universities, under the leadership of David Packard and Yale Professor Allan Bromley, concluded in its 1986 report that "our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support." The Panel recommended a new federal investment strategy for university research, including policies which recognize that research facilities and equipment are a necessary part of federally sponsored university research. The Panel recommended, as one part of a comprehensive infrastructure investment policy, that a research facilities fund be established in the National Science Foundation for ten years, funded at $500 million per year. From these funds NSF would award competitively 50/50 matching grants for facilities modernization. The Panel emphasized the need to fund the facilities program with incremental funds and not at the expense of ongoing federal research programs. The Panel's report states:

> ". . .present support levels are already inadequate to the national demands on the universities. Given this fact, important as the demands for infrastructure are, were they to be met by an effective 10 percent cut in the level of support for actual R&D, the consequences within the university research community would be devastating . . ."

The magnitude of the university infrastructure shortfall has been examined extensively in recent years with estimates covering a very wide range. Quite independently of the Fuqua initiative (H.R. 2823), the Panel arrived at the same estimate of the necessary minimum program scope–$10 billion over the next 10 years with $5 billion from federal and $5 billion from non-federal sources (pp. 14-15).

This analysis may appear abstract and speculative, but my time as President has led me to conclude that the problems described above are indeed very real. Let me turn then to the impact of the facilities problem upon one particular campus–my own.

- Chemical Engineering: A faulty air handling system permitted humidity to build up and destroy a salt crystal operating as the beam splitter of an interferometer, causing research delays and several thousand dollars in additional costs to the University. Variations in humidity levels may cause malfunctions in computers and instrumentation and actually destroy spectrometers and other sensitive devices.

- Cell Biology: An imperfectly functioning temperature control ended a fifteen-year old experiment by destroying a genetic stock collection (fruit flies). Although valuable results had been obtained from the experiment, its premature termination required additional expenditures and a three year delay to partially replicate lost materials. Some information was irretrievably lost.

- Chemistry: Recently discovered deterioration in the roof of Yale's major chemistry facility, constructed in 1923, may require the relocation of several research groups and teaching space. Relocating laboratories inevitably causes disruption of on-going experiments and delay in research programs and general loss of momentum in the affected department.

When we began to ask ourselves why these kinds of incidents were occurring, we learned the following. Two cycles of aging and renewal drive the capital requirements of the experimental sciences: Decay of the physical plant and obsolescence of laboratories. These cycles have different periods. Major renovation of the exterior envelope and utility systems may insure the integrity of a structure for up to fifty years. The outer time limit between renovations required to keep laboratories on the cutting edge of research is less than a decade.

Safety is a third element affecting the capital requirements of advanced research. States have enacted more stringent fire codes. The substances used in laboratories have grown more hazardous, and increased understanding of their dangers as well as more rigorous federal and state standards governing their environmental treatment, storage, and disposal have added heavy costs to the continuance of research. These costs cannot be deferred.

Older institutions which have grown up with and contributed to scientific progress find themselves at a costly point on both cycles at once. Over 90% of Yale's science facilities are more than two decades old. (See Figure 4.) Half of the original

construction of science facilities at Yale took place before 1940, and for some of these, re-configuring them for modern research will be more costly than building new facilities. Steam and power distribution systems as well as exterior walls and roofs are reaching the end of their useful lives in many of these structures. When new technological and environmental safety requirements are taken into account, only 12 percent of Yale's scientific space is deemed not to require major rehabilitation in the next five years.

YALE UNIVERSITY (EXCLUDING SCHOOL OF MEDICINE)
NEW SCIENCE CONSTRUCTION BY DECADE

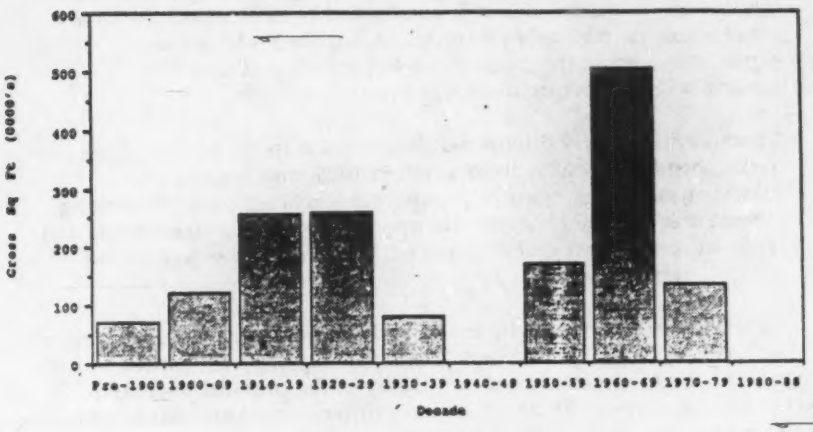

Figure 4

How do these needs translate into dollars for Yale? Yale's Science Capital Planning Committee has estimated that the cost of bringing the University's non-Medical School science research and teaching laboratories, and the buildings in which they are situated, to a reasonable level of physical and technical modernity is about $130 million, to be expended over five years. Based on the University's experience with fund-raising and its tax-exempt borrowing ability, funding sources are not identified for more than about two-thirds of this amount. Table 1 summarizes these costs.

TABLE 1

RECOMMENDATIONS OF YALE SCIENCE FACILITIES
CAPITAL PLANNING COMMITTEE
(in millions of dollars)

Rehabilitation and Renewal
Science Facilities (Excluding School of Medicine)

	Funding Expected	Fund Sources Not Identified	Total
Research and Teaching Labs	21	67	88
Building Structure, Systems and Safety	24	17	41
Total	**45**	**84**	**129**

Unfortunately, less than half of the funds from already identified sources can be made available for actually upgrading teaching and research laboratories. Before research can be conducted, the buildings that house it must be sound. The University is anticipating urgent structural and safety projects for its non-Medical School science facilities totalling $24 million. Of these, projects totalling $12 million are needed to preserve the buildings and their systems; the other $12 million will provide safety improvements. Preservation expenditures include outlays to keep ceilings and walls from crumbling, to upgrade power distribution systems designed in some cases for 19th-century teaching laboratories, and to refurbish plumbing systems not made to accommodate modern laboratories. Safety expenditures will include $6.5 million in air handling projects over the next five years; $3.3 million for fire safety; and $1.6 million for the disposal and storage facilities for chemical substances.

The University has no choice but first to assure the overall physical integrity of its research plant and the life and health of building occupants. Since funds are limited, and these needs must have priority, investment in the renewal of existing scientific laboratories to bring them to a level reflecting the current state of industrial and academic research activity is severely constrained. Only $21 million of $88 million in high priority laboratory renewal projects identified by our Science Capital Planning Committee can be paid for with funds we anticipate receiving from identified sources (including tax-exempt borrowing). We will devote $10 million in the next five years to rehabilitate the laboratories of 30 senior investigators alone,

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and this will represent but a portion of the cost of upgrading all of the research laboratories to a condition consistent with current scientific standards. We must spend approximately $10.6 million to create "clean" laboratories with particle-free air in electrical engineering, geology and geophysics; a consolidated teaching laboratory for engineering and applied sciences which will employ the University's combined engineering resources more efficiently; and upgraded labs for biophysics and biochemistry.

This will leave us without funding for some $67 million of defined high priority laboratory modernization projects. These include the renewal of many antiquated labs; the provision of adequate research facilities for biotechnology; bringing undergraduate biology teaching facilities out of the 19th century; and the expansion and automation of science research laboratories. It should be emphasized that this discussion concerns only facilities renovation and excludes any consideration of the need for new construction required to allow expanded research programs.

This, then, is why we have need for remedial action, and why that action is a matter of tremendous concern not only to me but broadly among the presidents of institutions like Yale. Let me suggest that Senator Dodd's proposal brings together many of the key elements of a program to address this situation which warrants the support of Congress. In particular, I offer on behalf of the AAU and several other associations the following comments and suggestions:

1. The Dodd Amendment represents a first step toward the national reinvestment strategy called for by the White House Panel. It is particularly gratifying to see the Dodd Amendment's provision for the open, competitive, merit-based allocation of scarce facilities funds. I and the AAU strongly support the criteria for the award of funds and the requirement for matching funds. In our view, curtailment of the competitive process, by the imposition of geographic caps, would pose a serious threat to the integrity of this federal research program. Geographical considerations already do and should enter as a criterion in merit review process.

2. The two-tier feature of the program recognizes the needs of the institutions most heavily engaged in federally supported research while also providing a special opportunity for smaller or emerging research institutions to compete for funds. We support this feature in that it preserves the principle of merit-based selection, including for this special group of institutions. The Dodd Amendment also provides a special opportunity to institutions serving a substantial number of minority and disadvantaged undergraduate and graduate students to compete for a separate component.

3. The funding authorization proposed in the Amendment as reported

by the Committee on Labor and Human Resources begins at $47 million for FY 1989 and $95 million for FY 1990, with authorization for "such sums as may be necessary" for each of FY 1991 and FY 1992. This authorization is only a fraction of the $500 million per year over ten years that the White House Panel estimated should be spent. I would therefore urge the Committee to make an authorization which builds toward the $500 million per year level. Appropriations to support the facilities to carry on basic research should not diminish the level of support for research activities by NSF; adequate facilities are a precondition and not a substitute for the basic research that will serve this nation's needs. In particular, funding for investigator-initiated research should reflect the commitment to double funding for the NSF over the next five years.

4. The Dodd Amendment addresses only the research facilities needs of universities and colleges. We support the proposal for a separately authorized, funded and managed matching-grant program to modernize undergraduate instructional facilities, as outlined in the letter of April 11 to the Committee from the American Association of Community and Junior Colleges, the American Association of State Colleges and Universities, and the National Association of Independent Colleges and Universities, as well as the other associations participating in this statement. The need for such a program will be addressed by other members of this panel. Therefore, I will conclude by commending to your attention the concerns of undergraduate colleges. I can assure you that research universities understand the instructional facilities needs of these institutions because they face identical problems. As you will hear, the needs are real, the consequences of neglect are severe and the case for federal leadership is strong.

I will be pleased to respond to your questions.

The CHAIRMAN. Thank you very much.

Dr. Dunn, would you pull the microphone over and proceed, please?

STATEMENT OF DR. MARY MAPLES DUNN, PRESIDENT, SMITH COLLEGE

Dr. DUNN. Mr. Chairman and Members of the committee, I am Mary Maples Dunn, President of Smith College, a college for women.

My main message to you this morning is a simple one. If you want to make a positive impact on our nation's scientific capability and leadership, your best investment may be in undergraduate liberal arts colleges. Many studies, most recently those by Oberlin College and Elizabeth Tidball, have demonstrated that America's undergraduate colleges have made a disproportionate contribution to this country's pool of scientists.

For the last 30 years, liberal arts colleges have constituted the majority of the 25 schools ranked highest in the percentage of their graduates who earned Ph.D.s in the sciences. And liberal arts colleges form the majority of the schools judged tops in per capita production of NSF Graduate Fellowship Recipients.

Clearly, liberal arts colleges are remarkably productive in preparing students for careers in the sciences, and the question is how this bears on academic research facilities. A substantial amount of scientific research occurs at liberal arts colleges. The scale of research projects at our colleges may be small, in keeping with the size of our institutions, and the pace of research is limited by our faculty members' dedication to teaching. But the quality and the importance of the research at liberal arts colleges is of the highest level, as measured by publications, grants and national recognition.

We believe that the best way to encourage undergraduates to pursue scientific careers is to involve them with hands-on science with the research faculty. Because our faculty focus on undergraduates, our students enjoy the collaboration usually availably only to graduate students at large universities. For many of our students, this research partnership is the critical factor in their decision to choose scientific careers.

But if we are to continue to be productive feeder schools for graduate programs, funds must be found to renovate, maintain and expand our aging research facilities. Our science buildings are old. A recent survey of 50 liberal arts colleges found that the average age of our science buildings was 50 years, and they had not been renovated for 20 years. Even 20 years ago it was not possible to anticipate the computers and instrumentation required by today's generation of scientific research.

With the struggle to afford state of the art equipment comes the dilemma of where to house it. Our experience at Smith may be typical. Following the renovation and expansion of our facilities in the early sixties, we experienced tremendous growth in all aspects of our science program. The number of students graduating with science majors more than doubled, science faculty increased by 50 percent, and there was a dramatic increase in the quality and quantity of research by faculty and students.

To accommodate this growth, we have had to relegate research activities to every space we can find, including storerooms, closets and other spots not really intended for research. Estimates for renovation and modernization of those facilities approach $4 million.

Federal funding for undergraduate science education is really inadequate. In 1984–1985, Federal funds underwrote 50 percent of the cost of new instrumentation at research universities but only 15 percent of similar costs at liberal arts colleges.

In your authorization for NSF, I hope you will recognize the importance of liberal arts colleges to the advancement of science. Furthermore, I hope you will put teeth in the authorization by recommending and supporting appropriation of new funds for undergraduate research facilities. At this time of critical need, it does not seem wise to me to fund one program at the expense of another.

Finally, as president of a liberal arts college for women, I call your attention to the fact that women are still underrepresented in all of the scientific disciplines. Our nation is neglecting a large, untapped resource of potential scientists, mathematicians and engineers. All baccalaureate institutions enjoy greater success in attracting women to science than universities, and women's colleges are the most successful at preparing for the future women scien-

tists who will be needed to maintain this country's scientific strength.

At a time when our country appears to be losing its leadership role in science and technology, at a time when the number of college science majors is declining, at a time when the number of advanced science degrees awarded to U.S. citizens is falling, it is imperative that Congress, through the NSF, take a leadership role in revitalizing science programs in educational institutions at all levels and for all people. The magnitude of the problem is large, and the long term implications are profound. It takes years to prepare a new generation of scientists. Therefore, swift, effective action is needed now.

Thank you very much.

[The statement follows:]

STATEMENT OF MARY MAPLES DUNN, PRESIDENT OF SMITH COLLEGE

Mr. Chairman, Members of the Committee, Distinguished Colleagues, Guests. I am very pleased to have the opportunity to speak to you concerning the National Science Foundation and academic research facilities.

My main message to you this morning is a simple one: If you to make a positive impact on our nation's scientific capability and leadership, perhaps the greatest return, dollar for dollar, will be from investing in scientific research at undergraduate liberal arts colleges.

By almost any measure, liberal arts colleges are remarkably productive in preparing college students for careers in the sciences. Many studies [1-7], most recently those by Oberlin College [3,6] and M. Elizabeth Tidball [5], have demonstrated that America's undergraduate colleges have made a disproportionate contribution to this country's pool of potential scientists.

Over the last 30 years, liberal arts colleges comprise 15 of the top 25 schools in terms of the percentage of their graduates who go on to receive Ph.D.'s in the sciences. Similarly, data on the *per capita* production of NSF Graduate Fellowship recipients, National Academy of Sciences members, and authors of most cited scientific papers all show that liberal arts colleges form a majority (14, 15, and 15, respectively) of the top 25 schools in terms of these measures.[6]

We are in the middle of a major demographic decline in the number of college-age students (18–24) that will continue until the mid-1990's.[7] At the same time there appears to be a significant decline in the proportion of college students interested in basic science programs. From 1975 to 1984, the proportion of freshmen at public universities intending to major in science fell from 13 percent to 8 percent. At the 26 most selective private universities, those intending to major in science dropped from 26 percent to 17 percent. But at the top independent liberal arts colleges, the numbers remained relatively constant during this period—between 28 and 31 percent.[6] These data suggest that liberal arts colleges will remain exceedingly productive feeder schools for graduate programs in science, offering some hope at a time of dismal predictions about the future of the sciences in the United States.

What makes liberal arts colleges so productive and how does this bear on an authorization bill for *research* facilities.

We believe that the best way to teach the sciences and to encourage undergraduate students to pursue scientific careers is to involve them with hands-on, significant participation in the process of discovery with faculty members actively engaged in scientific research.

Because our faculty members focus their teaching on undergraduates, our students enjoy a degree of collaboration usually available only to graduate students at large universities. Undergraduate students at liberal arts colleges are primary partners in this research. Evidence for this participation was gathered by the Oberlin study, which found that from 1980 to 1984, undergraduates coauthored *nearly one third* of all the scientific journal articles published by the liberal arts college faculty in their study group. In contrast, undergraduates at major research universities coauthored *less than one percent* of the journal articles published by university science faculty.[3,8]

For many students, this active participation is the critical factor in their decision to choose a career in the sciences. The success of this strategy is documented by the statistics just cited.

Quite a substantial amount of scientific research occurs at liberal arts colleges, some of it funded by the National Science Foundation and other federal agencies. Over the five years of one study, three-fifths of the liberal arts science faculty polled reported publishing research findings in each of those year.[3] The *pace* of research at liberal arts colleges is limited by the fact that our faculty members are dedicated teachers. The *scale* of research projects at liberal arts colleges may be small, in keeping with the size of our institutions. But the *quality* and *importance* of the research is of the highest level.

At Smith, science faculty members receive external funding and attract national attention in their disciplines for their work or problems ranging from star formation to acid rain to muscular distrophy to graph algorithms for spanning forests. Active, quality research programs by faculty members who welcome and invite undergraduate student participation are the major ingredients in our recipe for future scientists.

If liberal arts colleges are to continue to supply well-prepared students to graduate programs in the sciences, federal and foundation funds will have to be found to restore, maintain, and expand their inventory of aging reseach facilities. The facilities problems faced by liberal arts colleges are similar to those of research universities. Our science building are old: a recent survey of 50 liberal arts colleges found that the average age of their science buildings was approximately 50 years, with the average most-recent renovations undertaken 20 year ago.[4] These buildings were not designed with a knowledge of what the requirements of the next generation of scientific research would be. It was not possible to anticipate even 20 years ago the role that computers would play in the sciences and the dramatic advances in instrumentation that would accompany the miniaturization of electronic components.

Equipment needs overwhelm the small budgets of our science departments and can be met only with grant funds and donations. Today's chemistry students are asking questions that must be answered with nuclear magnetic resonance spectrometers, physics students are exploring the workings of lasers, geology students are interpreting rock chemistry using data from x-ray spectrometers. Scientific instruments are like automobiles: even with proper care and maintenance, replacement at a significantly greater cost is inevitable. Science is expensive. Colleges as well as universities are struggling not only afford state-of-the-art equipment, but also to find suitable places to house it.

I suspect that our experience at Smith in typical of many liberal arts colleges Following the renovation and expansion of our science facilities in the early 1960's, we experienced a tremendous growth in all aspect of our science program: the number of students graduating with majors in the sciences more than doubled; the number of faculty members in the sciences increased by half; the quality and quantity of research by faculty and students, as measured by research grants and scientific publications, dramatically increased.

To accommodate this growth we have sacrified astronomy teaching labs for a computer resource center, we have constructed a geochemistry lab for acid rain studies in a hoodless storeroom, and we have created a physiological psychology research lab in a converted incenerator room. We are bursting at the seams with many research activities relegated to inappropriate space not designed for research of any kind. Estimates for the cost of renovation of our existing facilities approach $4 million, with the cost of an additional building likely to approach $10 million. These are major expenditures for any institution, but especially so for a liberal arts college. The possibility of some support from the National Science Foundation for the updating and improvement of research facilities will encourage more liberal arts colleges to undertake projects like the one we hope to complete a Smith.

Historically, the National Science Foundation has recognized, through a variety of programs, the importance of liberal arts colleges to the overall scientific enterprise in the United States. Acronyms for these programs, such as URP, ISEP, SCIP, COSIP, and CAUSE [9], should be familiar to thousands of the leading scientists in our country today. With the arrival of the 1980's increased competition for an increasingly inadequate budget led NSD to eliminate most programs aimed primarily at undergraduate institutions.

The comparatively recent introduction of the RUI and CSIP [9] programs have, we hope, market a reversal of the downward trend of support for college science. Nevertheless, the actual dollar commitment to research at primarily undergraduate institutions and undergraduate science education in general is woefully inadequate. For example, at research universities in 1984–85, over 50% of the cost of new instrumentation was provided by federal funds. In contrast, only about 15% of the cost of scientific equipment purchased by liberal arts colleges during the same period came from federal funds.[6]

I hope that in the authorization for the National Science Foundation, the true importance of liberal arts colleges to the advancement of science will be recognized. I hope, furthermore, that you will put teeth in the authorization by recommending and supporting appropriation of *new* funds. At this time of critical need, it is not wise to pit one science program against another in competition for inadequate funds.

Finally, as president of a liberal arts college for women, I want to take this opportunity to point out the significant role women's colleges play in this process. As you surely know, women are underrepresented in all the scientific disciplines, receiving only about one in every six Ph.D.'s awarded in the natural sciences. In a variety of subtle and not-so-subtle ways, our society discourages women from pursuing careers in the sciences. Because of this, our nation is neglecting a large, untapped resource of potential scientists, mathematicians, and engineers.

Of all baccalaureate institutions, women's colleges are the most successful at attracting and preparing future women scientists. The proportion of women who graduated during the 1970's who went on to earn Ph.D.'s in the natural sciences from 1974 to 1985 was nearly 20 percent higher for women's colleges than for coeducational colleges.[5] If the federal government is to continue to take the lead in attracting women to the sciences, as it has in establishing the NSF Program of Research Opportunities for Women, then the special role played by liberal arts colleges for women in opening the doors of science to women should be recognized by giving them equal access to National Science Foundation funds.

At a time when our country appears to be losing its leadership role in science and technology, at a time when the number of college students majoring in science, mathematics, and engineering is declining, at a time when the total number of advanced degrees in the scientific disciplines awarded to United States citizens is falling annually, it is imperative that Congress, through the National Science Foundation, take a leadership role in revitalizing the science programs at our educational institutions at all levels. The magnitude of the problem is large and the long-term implications for our nation are profound. Because it takes years to prepare a new generation of scientists, swift, effective action is needed.

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COSIP: College Science Improvement Program
CSIP: College Science Instrumentation Program
ISEP: Instructional Scientific Equipment Program
RUI: Research in Undergraduate Institutions Program
URP: Undergraduate Research Participation Program

The CHAIRMAN. Thank you, ma'am.

Dr. Courtice, we can go ahead. Our distinguished colleague is here now.

STATEMENT OF DR. THOMAS B. COURTICE, PRESIDENT, WEST VIRGINIA WESLEYAN COLLEGE

Dr. COURTICE. Mr. Chairman, Members of the committee, my distinguished Senator from West Virginia, Senator Rockefeller, it is a pleasure to testify about undergraduate science facility needs. In addition to my written statement and with your permission, Mr. Chairman, I would like to submit for the record[1] a study of science facilities that has been compiled by the National Institute for Independent Colleges and Universities.

The CHAIRMAN. It will be included by reference.

Dr. COURTICE. I am here to urge that you authorize new National Science Foundation programs that would include funds for the renovation and the construction of science facilities used for undergraduate education and research.

I want to stress a single basic point in that discussion and echo my colleague from Smith College, and that is the critical importance of the role of the undergraduate college in preparing scientists. I can do this best by sharing with you just a few brief observations about my own institution in West Virginia, for I think they are observations that can be made about a wide band of American undergraduate colleges, the feeder system for graduate and professional programs in the sciences.

Wesleyan enrolls about 1,300 undergraduates in 35 degree programs. Almost 25 percent of our students are studying the sciences, with majors in physics, chemistry, biology, mathematics, computers sciences, engineering, physics, and as Senator Rockefeller said earlier this morning, we have formal agreements with the University of Pennsylvania leading to master's degrees in engineering.

There are good reasons why Wesleyan and undergraduate schools like us play such a critical role as this singularly important feeder system and why I think we can help to seal two of the leakage points Dr. Bloch has mentioned this morning, at the first year of undergraduate study and as students leave their undergraduate programs to go on to graduate school.

First of all, the educational environment on our campus is distinctly encouraging and nurturing. Students receive a great deal of one-to-one attention from their faculty. No student who really tries and has the ability falls on his or her face. Some of our best science students have had a rocky start at the beginning of their undergraduate careers, but encouragement to try again, to retest or to re-enroll in a tough course has produced some eminently qualified science students. Undecided students at Wesleyan receive the time and the attention from faculty for sorting through their interests and abilities, and many get turned on to specific fields in science through this process.

Secondly, the faculty on these campuses, while staying abreast in their fields through their own research, are first and foremost devoted to teaching. One of our chemistry professors used a portion of his much sought after and highly valued sabbatical leave to travel to rural high schools in southern West Virginia helping high school

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[1] The statement is in the Committee files.

teachers to learn how to improve their own science programs and their own teaching techniques.

And finally, our programs are challenging and rigorous. At Wesleyan, 90 percent of all science majors are in the top 25 percent of the student body, and all science majors are required to do some piece of original research in order that they graduate.

All this, however, is being done in science facilities that need attention. In our case, the science building, Christopher Hall, was built in 1967. At the time, the building was well designed and accommodated departments of chemistry, math, biology and physics with first rate facilities. Science has changed since 1967, and without diminishing the quality of the original program and without deleting crucial courses, new curricula have been necessary, specifically in the areas of computer sciences and engineering physics. However, we have had to do this without adding or renovating our existing science building.

Christopher Hall's original design included spaces devoted to faculty and to undergraduate student research, and that space has since been taken over by computer and engineering labs. With these new majors and increased enrollments but no new space, the science faculty has forfeited research space, an important teaching tool, and a source of personal renewal.

I hope I will not sound too presumptuous when I say that Wesleyan, the National Association of Independent Colleges and Universities and other education groups would be pleased to design a much-needed and long overdue program with the National Science Foundation and with this committee in order to provide funds for the undergraduate facilities used in science instruction.

This program should not be an entitlement but one grounded in the peer review system to select the most worthy projects. I am confident that campuses would be willing to work with the National Science Foundation and indeed match NSF funds with our own funds for these uses. We need, however, your support to do this.

Thank you, Mr. Chairman, and I, too, would be delighted to answer any questions.

[The statement follows:]

STATEMENT OF THOMAS B. COURTICE, PRESIDENT, WEST VIRGINIA WESLEYAN COLLEGE

Mr. Chairman, Members of the Committee, I am Thomas B. Courtice, president of West Virginia Wesleyan College in Buckhannon, West Virginia. I am here today on behalf of my institution as well as the West Virginia Association of Private Colleges and the National Association of Independent Colleges and Universities, whose membership includes more than 800 independent colleges and universities nationwide. I am also presenting the views of the American Council on Education, the American Association of State Colleges and Universities, the Association of American Universities, and the National Association of State Universities and Land-Grant Colleges, representing the vast majority of the nation's colleges and universities. Each of these groups support the request I am making for a comprehensive response to the urgent need for improved science facilities. We urge you to authorize new National Science Foundation (NFS) programs to provide funds for the modernization of science facilities for undergraduate education and for graduate research. I appreciate the opportunity to appear before you this morning and to discuss specifically the facilities needs of undergraduate science education at a college like Wesleyan.

West Virginia Wesleyan College, founded in 1890, is affiliated with the United Methodist Church. We enroll approximately 1,300 students in thirty-five degree programs. Almost 25 percent of our students are studying the sciences, with majors in biology, chemistry, mathematics, physics, computer sciences, and engineering phys-

ics. We also have articulation agreements leading to masters degrees in engineering, with the University of Pennsylvania and Langley-NASA Research Center. Wesleyan is additionally distinguished because a member of this committee, Senator Jay Rockefeller, served as its president from 1973 to 1975. Senator Rockefeller has continued to be a strong supporter of higher education and it is a privilege and pleasure to appear before him today.

Our nation's future competitiveness depends upon quality undergraduate science and engineering preparation of our students today. Science education involves both classroom learning and hands-on laboratory experimentation. Therefore, for the sciences, quality teachers are not enough to guarantee successful education—students must have the most up-to-date equipment and facilities. It is crucial that our undergraduate science and engineering students have good resources, including appropriate laboratories and equipment in order to realize their full potential.

The education of future scientists, engineers, and science teachers does not solely belong at the graduate level. In 1985, a task force of the national higher education associations reported that:

> The process of science, engineering and technical education, and the education of scientists, engineers and technicians is continuous. The undergraduate years are a crucial phase in that process. They are the years when qualified students learn the basic scientific concepts in sequential study and weigh career choices as professional engineers, scientists and teachers. The federal concern with the production of trained scientific and engineering manpower thus requires direct and appropriate investment in undergraduate education—research and instrumentation and teaching programs—in all its settings, whether at two-year or four-year institutions, or in undergraduate programs at research universities.

Many undergraduate institutions have a strong tradition in the field of sciences and engineering, and also a great potential to increase their yield of scientists, engineers, and technicians. It is important to note that some small undergraduate schools have historically attracted science students of high ability and produced a disproportionately large number of science and engineering graduates, as well as a large percentage of students pursuing science and engineering at the graduate level. In West Virginia, for example, the two colleges who graduate proportionally the most Ph.D. candidates in the sciences are Bethany College (with an enrollment of less than 1,000 students) and West Virginia Wesleyan.

Thus, the federal responsibility toward increasing the science and engineering capability of our nation naturally extends to the under-graduate college and university. One of the strongest statements in support of federal funding for undergraduate science was made by the National Science Board's (NSB) Task Committee on Undergraduate Science and Engineering Education—a principal advisory body of NSF—(also referred to an the "Neal Report" after its chairman, Dr. Homer Neal). The Neal Report states that "current national policy and federal strategy recognize that education in science, engineering, and mathematics are critical to the economic vitality and security of the nation. Accordingly, heavy investments are being made in graduate education and research, and strong programs have been initiated to improve the effectiveness of pre-college education." The report argued that "sound national policy requires that the strategy be made complete by supporting the revitalization and imporvement of undergraduate science education." Also, the report pointed out that "the enabling legislation for NSF obligated it to take leadership of efforts to revitalize and improve undergraduate mathematics, engineering and science education in the United States."

The NSB Task Committee urged NSF to establish a permanent presence in undergraduate science education comprising: 1) a comprehensive set of programs to catalyze and stimulate national efforts to assure a vital faculty, maintain engaging and high quality curricula, develop effective laboratories, and attract an increasing fraction of the nation's most talented students to careers in engineering, mathematics, and the sciences; and 2) a mechanism to inform the nation systematically of the condition, trends, and opportunities in these important areas of education.

Clearly, these recommendations coincide with the message you are hearing from colleges and universities in your states that a crucial component of such large scale support for higher education is the investment of federal funds in our science buildings. As you know, science and engineering education require observation and experimentation. Therefore, laboratory study is central and critical to undergraduate education in the sciences. Most science students encounter their first reasearch science education at the undergraduate level. Therefore, well-equipped labs and up-to-date equipment and facilities are crucial to quality science education.

The most recent White House Science Council Panel on the Health of U.S. Colleges and Universities called for a major federal role in the area of facilities assistance, reporting that "our universities today cannot simply respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support." Moreover, a recent study by the National Institute of Independent Colleges and Universities (NIICU) asked colleges and universities to identify the facilities they need to provide adequate instruction in the sciences. The study showed the estimated need for spending on science facilities over the next three years in the independent sector is $1.6 billion, with $1.2 billion for construction and $.4 billion for repair and renovation. Keeping in mind that these schools represent about half of the higher education institutions and about 21 percent of the national enrollment, the total need for spending on science facilities is probably more than $3 billion.

The NIICU study shows that modern science facilities are in short supply on our college campuses—the training ground for our future scientists and engineers. The institutions surveyed estimate that 40 percent of their facilities are inadequate. Only 10 percent would call theirs state-of-the-art. Not all colleges are in the financial position to modernize their current science facilities or to construct new ones. During the past three years, the average spending per institution on construction was about $944,000. But more than half of the colleges such as Wesleyan spent no money on new construction. In fact, nine out of ten institutions spent an average of $535,000 each on repair and renovation over the same three-year time span.

In Wesleyan's case, as I suspect in many others, the science building, Christopher Hall, was constructed in 1967. At the time, the building was well-designed and accommodated the departments of chemistry, mathematics, biology, and physics, with first-rate facilities including a planetarium, a greenhouse, and extensive departmental laboratories. But science has changed since 1967. Without diminishing the quality of the original program and without deleting crucial courses, new curricula have been necessary, specifically in the areas of computer sciences and engineering physics. However, we have had to do this without adding to or renovating our existing science facilities.

With increasing enrollments of new majors but no new space, the science faculty have forfeited their research space. Christopher Hall's original design included spaces devoted to faculty and undergraduate student research. That space has since been taken over by computer and engineering labs. Undergraduate faculty need this space to stay fresh as scholars and challenging as teachers of prospective professional scientists.

I am joined by presidents of colleges across the country in this problem. The president of a college in Maryland said: "A recent chair of our Trustees' Long Range Planning Committee called our science facilities in one-half of our science building 'of Louis Pasteur's age' ". From the president of a college in Indiana came: "Computer science labs had to be moved to the former laundromat due to the condemnation of the [computer science] building." And a New York college president said: "We are using a building constructed in 1967. It was well designed at the time, but the number of science majors and science faculty have more than doubled with no additional space. Molecular biology of the 1980s and contemporary safety practices do not fit into the building design of the 1960s."

There can be no question but that the time has arrived to re-invest in our education science infrastructure needs. I can assure you that Wesleyan, NAICU and the other higher education groups will help this committee, design a much-needed and long-overdue program in the NSF to provide funds for the undergraduate facilities used for science instruction. Such a program should focus upon the more pressing modernization and upgrading needs and require a match of institutional funds to qualify. Even a relatively modest program could act as a catalyst for other funds.

I would like to emphasize that this program would be grounded in the peer review system to select the most worthy projects. I believe that the national Science Foundation possesses both the expertise and the administrative capacity to select the top projects from among the many who will request funds. This is consistent with NSF's longstanding role in ensuring our nation's leadership in science.

Senators Dodd and Kennedy, members of the Labor and Human Resources Committee, have testified today concerning an amendment they will propose to S. 1632 to create such a new authority within NSF. I am delighted that the Commerce Committee, with your joint jurisdiction over NSF research programs, will further explore how to begin to address this critical problem in our science infrastructure. Other testimony will be presented to this committee, describing the particular needs for improving our university science facilities and urging the creation of a new NSF program to meet those needs. Each of the groups represented in my testimony also

strongly supports need for a NSF program for research facilities. We urge you to give your attention to a comprehensive response to these pressing science needs. We stand ready to work with you.

Mr. Chairman, thank you for the opportunity to testify.

The CHAIRMAN. Thank you very much.

Dr. Brophy.

STATEMENT OF DR. JAMES J. BROPHY, VICE PRESIDENT FOR RESEARCH, UNIVERSITY OF UTAH

Dr. BROPHY. Mr. Chairman and Senators, I am Jim Brophy, and I am Vice President for Research at the University of Utah.

I am most pleased for this opportunity to testify on the subject of academic research facilities. My statement today is presented on behalf of my colleagues, both at the University of Utah and at other public research universities in the nation. In these comments I discuss the need for an academic research facility, renovation and construction program and the implications for the continued quality of university research without such a program.

I advocate an effort in which the colleges and universities of this country can participate in partnership with the Federal government in revitalizing research facilities. I firmly believe that without such a thrust we cannot keep this nation's science at the cutting edge. For more than 20 years we simply have not invested in the research infrastructure at a rate necessary to meet the challenges posed by international competition.

I am most pleased that this committee is contemplating the formal research facilities program proposed by Senator Dodd to be implemented by the National Science Foundation. The National Science Foundation has a vital role in leading the nation's investment in basic research. The Foundation's research programs provide more than one-third of the Federal support for basic research in our universities and colleges, and unlike other Federal agencies such as the Department of Defense and the Department of Energy, the Foundation maintains no laboratories of its own. All NSF research and education programs are carried out by universities, colleges and other non-Federal organizations.

The NSF has been a leader in seeking better modes for the prosecution of research at universities.

A federal role in support of research facilities is not a new concept. As recently as the early 1960's the United States had a strong commitment to the expansion of the nation's academic research facilities which resulted in the passage of several acts of enabling legislation. However, beginning about 20 years ago, most Federal agencies effectively withdrew as serious investment partners in research plant.

Recently, NSF and other research agencies have accepted leadership addressing another part or the infrastructure deficit, that is, the research equipment needs of universities and colleges. NSF investments in research equipment have grown from less than 10 percent of total research funds in the late 1970's to about 20 percent currently. Also, support of academic research by NSF and other Federal agencies has experienced growth in recent years. Nevertheless, neither the Foundation nor any other Federal research agency has in place competitive, matching grant programs

to help universities address the accumulated needs to modernize, repair, renovate or replace obsolete research laboratories that can no longer support the front line research that universities can provide and the nation needs.

Simply put, the total program is out of balance, and we must redefine research support to include the maintenance of the full research infrastructure.

While there appears to be universal agreement that we suffer from a facilities deficit, it is useful to understand better how this problem affects the conduct of research. At the University of Michigan, for example, a dean recently advised all researchers that "the inventory of research space is completely depleted," and that no grant applications may go forward absent a plan for space.

At the University of Utah, we are forced to spend more than $300,000 annually to rent space off campus for the School of Medicine, the College of Engineering, the College of Pharmacy, the College of Nursing, and the Artificial Heart Research Laboratory. We rent this space because we have been unable to accumulate capital funds to construct appropriate facilities on campus. To do otherwise would mean that important research efforts in robotics, medicinal drugs and drug delivery, cancer research, and continued development of the totally implantable artificial heart would go undone.

Other important research programs are pursued in inadequate facilities on campus. The Laser Institute is housed in three separate buildings, and thus loses the close interaction between research faculty which we feel is most important to the success of the program. Our microelectromechanical systems effort is limited by available space, effectively restricting our contribution to this exploding new field. The University is contemplating extensive renovation of decades old space to support our major research program in cosmic ray physics supported by the National Science Foundation. These are only a few examples at one public research university, and similar situations exist at our sister institutions.

The present facilities use allowance and depreciation provisions of the Federal Cost Reimbursement Regulations in OMB Circular A21 are outdated. Under these provisions, the useful life of research equipment is 16 years, which is about three times the useful life of most analytical equipment. The use allowance for research laboratories also fails to recognize that modern research plants have a useful life of perhaps 20 years, while the present cost reimbursement rules are predicated on a useful life of 50 years.

For all of these reasons, I urge the committee to enact legislation that has the following goals: one, the National Science Foundation should be granted renovating and construction funding authority for academic research facilities. Two, the award process should be governed by merit review with clear criteria for awards. The authority should include provisions for four years colleges and emerging institutions, taking into account such factors as preparation of students for academic careers and the underrepresentation of minorities in the sciences. These provisions should not override merit review, but should be part of the consideration of proposals. Three, institutions should be required to match Federal funding in some systematic way. Considerations should be given to a flexible match

with a greater Federal portion allowable for projects in categories of national interest such as facility renovation to meet federally mandated requirements for animal care or health and safety. And finally, four, indirect cost recovery should fully fund facility depreciation and use.

Mr. Chairman, I appreciate the opportunity to discuss these concerns and will be pleased to respond to any questions.

The CHAIRMAN. Dr. Brophy, under your criteria, do you think that Dr. Smith's school over there would ever get any money from the National Science Foundation under the program?

Dr. BROPHY. I believe you misunderstand my criteria. What I am saying is that the criteria should include and recognize the contribution that such institutions do make. I am not sure that the program should necessarily be a head-to-head competition between research institutions and four year colleges.

The CHAIRMAN. We have been in the discipline up here for quite a while; merit, peer review, it is all the same. Dr. Courtice, Dr. Smith, they all want peer review.

Mr. Schmidt, under your approach, do you think that Dr. Smith—and that is my task here, to get the two Schmidt-Smiths together—do you think Dr. Smith would ever get anything?

Mr. SCHMIDT. Yes, he would, Mr. CHAIRMAN.

The CHAIRMAN. How?

Mr. SCHMIDT. Well, I support both provisions of Senator Dodd's amendment, one that would create a special category of facilities research support for emerging institutions, and secondly, that would likewise create a special category for historically—for institutions that have historically served minorities.

The CHAIRMAN. You are talking sense now. I did not read the original Dodd amendment that way. In fact, he does not read it that way. He is worried about depending solely on merit and peer review, and what you said is salutary because I think the committee is going to have to deal in that fashion. The second Dodd amendment sounds better.

You see, the age of the building does not disturb me a bit. In my home town, we have the oldest municipal college in the United States; the buildings are 200 years old, and they are delighted to have them. Additionally, I had two older brothers, and while I do not know why we wore knickers, I was delighted to get their hand-me-down knickers, and I will bet you Dr. Smith would delightedly take Mr. Schmidt's beautiful buildings on the Yale campus and reconstruct them down into Orangeburg. He would be delighted to get those unsafe buildings you have got.

And yet we do not want to hold back excellence. I am not taking away from you. I am trying to be realistic. Yale has led the way. We do not want to take away from the private institutions. It would be very easy for a public servant to say look, our duty up here as public servants is to take care of public institutions, and our duty to the private institutions is to leave them alone. I do not think that is the best approach because there is excellence in these independent schools that must be acknowledged and supported, particularly in this particular discipline of science, and so we will.

But how do we balance it off. We want to put in a category for the emerging schools and for the minority or for the liberal arts

colleges. I like the emphasis on the small liberal arts institutions; that is what built the country. With such a provision they will have a chance, because otherwise the original Dodd amendment has been read to mean, let's take the rich and powerful universities that are all in these associations—the ones we cannot even get into, such as the Association of American Universities—and make them richer. Are you in that group, Dr. Smith?

Dr. SMITH. We are members.

The CHAIRMAN. You are members? Well, good, you are coming along then. You are doing fine.

I stand corrected.

What they say is that they have an amendment that was put on here by a good friend of mine who runs these things. Senator Dodd gets that original amendment on the bill, and then they have merit rather than use the word "peer," because he has learned not to use the word "peer" anymore, and you ought to smile, Mr. Schmidt. You are the lawyer, not Dr. Brophy.

What we have got is really a problem, and we are limited in funding. We are all over the nation trying to play catch-up ball in getting back into research activities, and then you want to rebuild the bricks and mortar, it is going to be difficult to do it all.

I just say that with respect for the outstanding panel that the committee has here today.

Let me yield to Senator Rockefeller.

Senator ROCKEFELLER. Mr. Chairman, I agree with you about the sort of philosophical dilemma. If there is a limited amount of money, how can we best place it? Everybody needs it.

And you can make intellectually an argument that if there are scarce dollars—and that is what we deal with these days—that this money ought to go to the places that can, as Erich Bloch said earlier make the best return on the taxpayers' dollar. The other side of the argument, though, is that you never really know sometimes where the best return will be.

I can remember when I worked for the Peace Corps, Mr. Chairman, I went out to a college, an all black college in Arkansas, Arkansas AM&N, as a Peace Corps recruiter. My job was to try and encourage students to come into the Peace Corps, and I went out there and did my work. I also went to Harvard and did my work, and I found it interesting that Arkansas AM&N had a higher proportion of its students going into the Peace Corps than Harvard did.

Now, that taught me in 1961 a lesson which I shall never forget, and that is that a place does not have to be big and famous in order to offer this country greatness.

With respect to West Virginia Wesleyan, Dr. Courtice, I might mention with some pride that I also had the chance and the honor to be President of that college for three years, and I know very well when you talk about Christopher Hall. That building had just been built about five or six years prior to my becoming President, and it was considered at the time that I was there a superb facility.

I know exactly what you mean when you talk about nurturing students, the Ernie Kapstacks, the Allen Hamners, the quality, the level of the science teachers with the fiercest commitment to science at that particular institution took a lot of students who might

have gone into some other field and put them right into the sciences and engineering. Wesleyan, as I indicated earlier, back in the 1960's ranked ninth in this whole country in terms of numbers of Ph.D. scientists turned out by liberal arts colleges. That is incredible when you think about that, a small campus in the middle of a rural state, and yet performing that kind of service for the nation.

On the other hand, Dr. Courtice, you come here now with a problem that you do not have the space, and you are having a hard time, I would guess, recruiting the kind of faculty that you want to come and teach at Wesleyan in the sciences because of the space problem.

Am I right about that?

Dr. COURTICE. Actually, there are lots of reasons why it is difficult to recruit good faculty, but the space, the facility question is one. We have had on campus in the last three weeks three candidates for a teaching position in engineering who commented on the quality of the equipment, the apparent quality of the students and the faculty that you have just mentioned, and all three in the course of their visits to campus did remark about the difference between that level of quality and what they saw in the building, the crowded conditions, and the fact that that part of the program just did not seem to be at the level that the other parts of the program had achieved.

Senator ROCKEFELLER. And so it was not the school, the ambience of the campus. It was just the fact they did not see themselves having enough space in which to do research or one-on-one work with students.

Dr. COURTICE. I think they were concerned about both of those factors, and I think that they had come to the campus expecting, given all that they had read and learned about the institution and the students who were there, to find that, yes, that is exactly right.

Senator ROCKEFELLER. What is the budget of West Virginia Wesleyan College?

Dr. COURTICE. About $14 million.

Senator ROCKEFELLER. How much money can you put in, Dr. Courtice, into the renovation of science laboratories in the course of a year?

Dr. COURTICE. In the course of a year, th dollars that go into the renovation are general maintenance dollars. There are no dollars outside of the special gifts program that we have available for the renovation of those facilities. It is simply patching a roof, a little paint here or there, but there are no dollars in that $14 million operating budget for the renovation or any new construction attached to that science building.

Senator ROCKEFELLER. So essentially you are saying that a four year liberal arts college which in my judgment and your judgment is a first rate one, and ranks very well across the country, has no way and no money to introduce new facilities, new equipment into its science program, even though that science program is participated in by 25 percent of the students and is a first rate one.

Dr. COURTICE. Well, not without that special effort that would involve outside gifts and outside support.

Senator ROCKEFELLER. If an alumnus should happen to pass on and have been a graduate of Wesleyan and dedicate that money to

the science program, obviously that would be helpful, but Wesleyan was formed in 1890 and it does not have the enormous reserve, at this point, of wealthy alumni that you can count on—well, I think I had better drop that subject. It is not a very pleasant one.

Dr. COURTICE. Alumni and friends.

Senator ROCKEFELLER. Yes, some of our best friends.

What would you in fact like to see the Federal government do to help you provide better science and engineering at Wesleyan?

Dr. COURTICE. Well, I think it is an easy response to talk about fiscal resources, financial resources, and yet I think it is at the heart of the problem, and as I said in both the written and the spoken testimony, I think it is essential that the undergraduate facility is not overlooked in this additional appropriation. I think at the same time it is critically important that the affirmative statement about undergraduate education, all of higher education be echoed throughout the Federal government.

And so to build on my plea this morning that there be additional attention paid in the NSF authorization for undergraduate science facilities, I think it is equally important that the place that postsecondary education holds in the future of this country be echoed throughout the Federal government and affirmed.

Senator ROCKEFELLER. Dr. Courtice, I thank you for being here. I really admire the work that you are doing at Wesleyan. It is a school with a distinguished tradition, and you are going to make it even stronger.

Dr. COURTICE. Thank you.

Senator ROCKEFELLER. Mr. Chairman, with your indulgence, I would like to ask Dr. Schmidt one question.

I used to watch you moderating discussions on public television, and I want to ask you, what is the ethical dilemma involved with scarce resources for, let's say, upgrading of science labs? We know it has to be done across this country. We know that liberal arts colleges as well as our great universities are all part of the academic training system. We know that we are falling behind not just the Japanese but others in terms of innovation, technical learning, engineering of various sorts. We have a lot of colleges. Some of them are better known and have deeper resources, and therefore have better capacity to deliver than others, and yet in this country we are all equal. We are meant to be a meritocracy. And because somebody is born in a place which is not famous or born in circumstances so that they cannot afford, let's say, the tuition at one of the more expensive universities, they ought to have that opportunity.

How should the Federal government draw an ethical line as to the distribution of funds?

Mr. SCHMIDT. Well, Senator Rockefeller, that is a difficult question and difficult to answer briefly.

I would say three things. One, I think an ethical perspective requires us to take a long view of our problems, and if you take a long view, you have to conclude that the nation needs to invest in the capital base, the infrastructure for its educational programs, whether advanced research programs at a place like Yale, or undergraduate teaching, which we do, too, at Yale, or in small, liberal

arts colleges, or anywhere. We must take a long view and recognize that we have to rebuild our infrastructure.

Second, I think we need to take a comprehensive view of the rich pluralism of our educational process and institutions in the United States. It would never be my view that a university like Yale should flourish while other essential institutions in our educational spectrum do not flourish. And I agree with everything that my colleagues have said. The pluralism of American education is its great strength, and we must work for excellence with a due recognition of our democratic traditions and the importance of pluralism.

And I think finally, and I do regard this as a first ethical principle in higher education: it ought to be the ability to learn and not the ability to pay that governs access to all institutions of merit of whatever size and whatever focus. That is why Yale admits all students of promise without regard to their ability to pay. That is why over 50 percent of the students at Yale are on financial aid. That is why financial aid is the fastest growing part of our budget, and I deeply believe in the importance of access and the democratic traditions that have marked higher education in this country, especially since World War II.

But it is compatible with all of those ethical principles, Senator Rockefeller, that the nation must invest in excellence in its scientific research. It will do that by a pluralistic policy that supports all kinds and types of meritorious institutions.

Senator ROCKEFELLER. Thank you very much, President Schmidt.

Thank you, Dr. Courtice.

Thank you, Mr. Chairman.

The CHAIRMAN. Did you have something to add, Dr. Smith?

Dr. SMITH. Yes, Mr. Chairman. I want to make a correction here. We are not members of the Association of American Universities, so you were absolutely right, but I would like to also make another comment, if time will allow at some point.

The CHAIRMAN. Mr. Schmidt covered you, though. I like that last statement he made because it shows a wonderful appreciation for our dilemma here at the committee level. We have got to maintain the excellence, we have to maintain the leadership. Certainly merit has got to be considered, but then it cannot fall into a syndrome where, as you have heard before, you have the peers, and I don't have any peers. For example, today I take it that Utah built a cancer center there on the University Campus. You talked about a cancer center.

Dr. BROPHY. Our cancer center at the moment is in rented space off campus. The program is supported by the National Institutes of Health.

The CHAIRMAN. The National Institutes of Health.

Well, you got in with the peers then because I just talked with Senator Byrd from West Virginia, and we had to struggle to get a cancer center in South Carolina. If you have cancer in South Carolina, you have to go to one of the three centers in North Carolina because we don't have the peers needed to win funding through the peer review process.

But Mr. Schmidt, you covered it well.

Dr. Smith, you had something to add?

Dr. SMITH. I just wanted to say that it occurs to me that the whole issue of partnerships and linkages between institutions of higher learning and not only institutions of higher learning themselves but also with the corporate community is important. I think that we certainly can work together. We recognize the outstanding capabilities of our research universities, but at the same time as we look at a wide base opportunity for youngsters across this country to be a part of this process, I think that that can best be accomplished if we do work together in some kind of partnership.

Some of that is taking place, but I believe, Mr. Chairman, more of that should be encouraged.

The CHAIRMAN. Very good. We thank each of you.

Senator Pressler.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you, Mr. Chairman, for scheduling today's hearing on reauthorization of the National Science Foundation.

The National Science Foundation fulfills a serious need in this country today. Just as we have to recover lost ground in America's space program, so too we have to recover lost ground in science education in this country. America is not producing enough scientists to fill its needs. The programs of the NSF are one way that this nation can encourage science education as well as scientific research.

I am particularly looking forward to the testimony on two issues today. First, I am interested in hearing about the proposal to provide facilities funding for undergraduate institutions. Second, I am interested in NSF plans to ensure a better geographic distribution of funds. South Dakota may seem off the beaten path to some, but we do have some excellent, if not large, universities in the State. These schools should be assured reasonable access to some of this funding.

The current system favors "established institutions." Schools which have established facilities attract more funding. But how do you originally get into the loop? It reminds me of the person fresh out of school looking for her first job. She's enthusiastic and well trained, but all the advertisements say, "experience wanted." That's exactly how the "less well established" schools feel when applying for NSF funding. We need to break out of this loop and broaden the geographic distribution of funding.

I would like to make just one more comment. The National Science Foundation has been funding the Continental Scientific Drilling Program. Last year's budget compromise resulted in a cut in FY88 funding for this program. The NSF funding proposal before us today, however, would restore a rate of growth which would double the NSF budget by FY92. If approved, this level of funding should also restore funding for the Continental Scientific Drilling Program to its originally planned levels. This program is essential if we are to maintain a position of leadership in earth science research. The benefits of this research are immeasurable. The knowledge to be gained in areas such as earthquake hazard reduction, permanent disposal of hazardous and radioactive wastes, and utili-

zation of petroleum and mineral resources is well worth the investment. The Senate recognized the importance of this program last year when it passed S. 52, the Continental Scientific Drilling and Exploration Act.

Mr. Chairman, I want to again thank you for holding this hearing today. I look forward to hearing this morning's testimony.

Let me say that I think most of the concerns I have, have been asked already, but I believe very strongly in the concept of getting some of these research funds to some of the smaller universities that are not so famous. I think there is a system, a network of peer review of the big ten, big eight, Ivy League, California sort of schools, where this money tends to go. In research and development, small businesses do most of the research and development in business, even though big corporations may claim to have large research departments; most of the innovations that we have in this country come from small businesses. Indeed, in terms of economic development in foreign countries, it is the small projects that have the longest term impact.

I just returned from Vietnam where I served some 21 years ago, and they still have motor pumps working, small, two horsepower motor pumps working that were delivered by USAID in the sixties. But all the grandiose, big projects are gone. And so it is in research.

I would say that we are largely paying lip service to getting some of this to some of the other schools. My state of South Dakota is a very small state in terms of population. We do not have the size of institutions, but we have produced some very good research, and I am very interested in the EPSCoR program. I am very interested in seeing some of this network broken up that there is, I think, sometimes in the peer review system, they pick one or two small schools and cite them as examples, but they do not make very much of a practice of it.

So therefore we need things like EPSCoR, but we also need a change of attitude, or Congress will act more. And I would rather Congress did not legislate this so specifically, but many of us from smaller states and with the universities that are not so famous or in the big ten or in the big eight are watching this very closely, and we would rather not legislate specifically. We would rather this be done on other bases.

But we will seek legislation unless there are greater efforts in this area.

Senator EXON [persiding]. I would advise the panel that we appreciate very much your being here, and there may be some additional questions that we would submit for the record.

Senator Rockefeller, do you have any questions for this panel?

Senator ROCKEFELLER. No.

Senator EXON. If not, thank you very much, ladies and gentlemen. We appreciate your contribution.

The last witness in front of the Committee today is Dr. Speser. I would like to have Dr. Speser please come forward at this time.

Dr. Speser, I want to take this opportunity to welcome you to this Committee. Your reputation as a leading thinker on science and technology is well known. Many of us on the Senate Budget

Committee know you as an outspoken advocate for Federal investment in science and technology.

I especially appreciate all the advice and assistance you have given me with regard to the technology trust fund concept. I am hopeful that we can move this idea forward in the near future.

And your coming here to testify this morning is very much appreciated. And I will be glad to recognize you for any remarks you care to make now. And then I will have a brief period of questions and hopefully answers. Please proceed.

STATEMENT OF DR. PHILIP SPESER, PRESIDENT, FORESIGHT SCIENCE & TECHNOLOGY INC.

Dr. SPESER. Thank you very much, Senator.

Let me before going into the substance of my testimony just say a few words about who I am and why I am here.

I hold a Ph.D. and a J.D. I am a member of the Bar of the District of Columbia also. I did my work at a public institution, State University of New York at Buffalo.

My academic work focused on what you can know and how you can know it, and what we can do with knowledge in both industry and in politics. I have taught at universities in the United States and West Germany.

Since coming to Washington I have continued to be active in Federal science policy, first as Special Assistant for Science and Technology at the Federation of American Scientists, and since 1981 as President of the company I founded, Foresight Science & Technology.

I have been actively involved with several pieces of legislation. Two of them are particularly important for what I will be talking about today.

One is the Small Business Innovation Development Act, which established SBIR programs throughout the Federal government. And the second is the Federal Technology Transfer Act, which went far towards opening up our Federal labs for more cooperative relationships with universities and industry.

I think the best way to sort of highlight the problem that I want to talk to is with my son's science project. My son recently was given the assignment of creating something that worked. And he decided he wanted to make a front lift loader.

He also wanted it to be powered, so he needed some basic research on what power is. So he came to me and he applied for funding and I gave him funding and we went to Radio Shack.

And at Radio Shack we bought some motors and a switch and a bunch of batteries and some wires, and we learned a lot about electricity and electrons and circuits. So we did some basic research.

Well, then we had a problem. We had all this basic research done and we had to do something with it because he still had to get the science project out, so he came back and he applied for some applied research funding.

With the applied research funding, we went to the play room and we took out some pieces from the tinker toy set, we got some rubber bands, we went and cut down a piece of bamboo and cut up a bunch of bamboo, and we got some string and some cardboard.

And we discovered how to make transmission mechanisms and gears that would take the power from the electric motor and convert it into something that you could do things with.

And finally he came back and he applied for a third set of funding for development.

The developmental funding bought the piece of wood, bought the glue that holds it on. I unfortunately dropped it on the way up here. I will have to explain that to him. And we made the little thing that goes on top of it that makes it look like a real front lift loader.

And the nice thing about it was he was able to go to one source and get multi-phased funding that carried him from the beginning of the project through to the end of the project.

Now, the problem that we have right now is highlighted by Eric Block earlier today in his testimony. He said that we need to make sure that we have true participation in the system.

We need to make sure that we bring our other institutions along, and we have to remember that they are very important and we should not forget individual investigators and small groups.

The problem is a very simple one. We have to figure out how to better utilize the genius residing at our Nation's science, math, and engineering faculties.

First, there is the need for long-term stable funding to take projects from basic research through to innovations. Second, there is a need to provide a source of funds to exploit breakthroughs in science, math, and engineering. And third, we need to improve retention, particularly at our Nation's smaller colleges and universities.

The program that I am going to talk to you about today that is based upon your legislation does precisely that.

I should add that this program would be restricted to college and university faculty, which means that I or my company would never be able to compete under it. I should also add that I am here on my own behalf today. If I represent anybody I represent my children.

I will not talk to you about the need for basic research funding because that has been talked about before this Committee so many times that we are all familiar with it.

Let me simply note that when it comes to long-term funding and the funding that allows you to address multi-disciplinary problems and take a problem all the way from fundamental research through to an innovation or coming close to that generic technology and generic applied research, university industry centers, engineering research centers, and science and technology centers allow addressing the lack of such funding that we have today and the consequences of little funding from the standpoint of big science.

Yet unfortunately there has been too little thought about mechanism to address this problem from the standpoint of little science. The only little science mechanism that has been developed is the SBIR program. That was originally developed by NSF, as we are all aware.

We need something that will enable the faculty at smaller schools, or in schools in poor states which cannot afford the upfront costs of competing for centers, to tap into funds that will allow them to do this kind of work.

I am very familiar with this first-hand. I was involved in putting together the Health Care Instrumentation and Devices Center, for example, for the State University of New York Research Foundation, and there is just a lot of upfront cost. And if you cannot afford to play, you cannot win downstream.

The SBIR mechanism, on the other hand, if we adapted it for something like a college and university innovation research program, would enable us to address the needs of faculty at schools unlikely to have centers or in departments unlikely to have centers.

Now, there is a second problem that we have to address in the fundamental research area that deals with faculty. What happens if you are on a standard NSF grant and you hit a great idea, and you have a breakthrough? How do you get the fast-track money?

Remember all the panic about superconductors that we had? People asked "Where are we going to fund these things?" There is no mechanism today that allows you to get fast-track money to carry through on major breakthroughs.

In the Department of Defense, of course, we have these things. The defense jargon for it is MIPPERing. Basically, if you have got a good idea they put some money in a contract, and you become a designated subcontractor. Or if you are working with the Department of Energy, they will put you through one of the Federal labs.

But in an agency like NSF, there is no vehicle to do that. An SBIR program which allowed people to compete in phase two on the basis of results coming out of standard NSF research grants would address that kind of program. Again, this is a program modeled on SBIR.

The third problem is probably the most tragic one, and that is the lack of adequate support for research by college and university faculty. Again, you have heard discussion of that earlier today. I will not go through it in great detail. Simply let me note that to be productive, faculty need time to explore ideas. And the reality that all of us who have been professors know when you are teaching is, that if you cannot get research support, you cannot reduce your teaching load. And if you cannot reduce your teaching load, even if you have got a great idea, you are never going to make the breakthrough. You cannot hire the graduate students. You cannot buy the materials.

This is America, there is nothing wrong with paying the people who teach our children well if they deserve it. It is widely recognized that research enlightens and enlivens teaching. NSF's programs, from SBIR to archaeology, demonstrate that Federal R&D support is the original merit pay. I think that it is appropriate to have a mechanism that allows people to pursue research ideas.

But there is a catch in all of this, of course. We are all familiar with the Federal budget crisis. And so we have got to try to think of ways to address these problems in a way that also keep in mind the budget crisis.

I feel firmly that it is the responsibility of the scientific and engineering community to explore and then propose new ways for increasing the revenues available for Federal R&D funding, as well as figuring out ways to spend those dollars.

Two years ago, with the Federal Technology Transfer Act, Congress introduced a new mechanism for funding Federal R&D. That mechanism is called recoupment. Essentially what happened is the government receives royalty payments on technology that are licensed out of Federal labs. That money is then funneled back into the labs. Some of it goes to the inventor, some of it the lab can use to fund further research. So it is like a user fee.

The recoupment mechanism, if carefully used, will enable the President, the Congress, and the agencies to leverage regrettably limited dollars. How could recoupment work in an extramural funding agency like NSF? Well, today awards are made primarily by grants and cooperative agreements. SBIR does use contracts, but I believe that is about the only research going out through contracts, through NSF. Because the Federal government owns the patent rights to the technology that is developed in Federal labs, it is appropriate to take royalties on patents as a way of recouping, should that be desired. However, with the research that is done at universities, the rights to that are owned by the university. So it would be inappropriate to take a royalty fee. A mechanism, however, that would enable for recoupment is the forgivable loan.

Forgivable loans are widely used in industry. Basically the project does not work out you do not repay anything. If it does work out you do owe something. As S. 1302 proposes, such recouped funds should go into a science and technology trust fund where they could be used for subsequent projects, and also for infrastructure investments at educational institutions.

Let me very quickly go over the structure of a college and university innovation research program, to just provide an outline.

It would be a two-phased program or three-phased program in effect, like the SBIR program is. I might note that the two-phased concept of Federal funding has become quite popular, since SBIR was developed and is now used, for example, in engineering research centers as well.

In the first phase, what you might want to consider is allowing for three or four years of money, $50,000 a year. The reason for allowing more money in the first phase than small businesses receive under the SBIR is that university faculty do tend to do more fundamental research that takes more time. Further by allowing for a longer period you do not have to pull faculty entirely out of teaching. (They also can fund some graduate students along the way. That is important because the number of graduate students being supported by the Federal government is now declining. And that of course hurts the country in the long run.)

The key in SBIR, of course, is the way in which proposals are selected. As in SBIR, we propose that you use the criteria of scientific and technical merit as a first funnel. Standard NSF peer review.

But once you get through that funnel, we can do some creative things. SBIR has indicated how that can be done. SBIR uses creative mechanisms for tie-breaking between proposals of approximately equal scientific and technical merit. In this case, we propose the following tie-breaking mechanisms.

First, to stimulate the economic development potential of the program, preference should be given to those proposals which are

accompanied by a plan for cooperation with a small firm located in the state of the principal investigator during the conduct of the research and during the subsequent commercialization of the research results.

In other words, in the case of Nebraska, if you had a PI at one of your universities and they wrote a proposal that made it through the first funnel, they could get a leg up in going through the second funnel if they established a tie with a small company.

The reason for that was indicated by the Senator just a few seconds ago when he noted the innovation made by small companies.

Now, I think it is important that we have a second funnel, however, because most people will immediately establish a tie-up. The second funnel is designed to address the problem of where research dollars go in the Federal government.

Notice that from the standpoint of the Federal government, and I would assume from NSF, if you are funding proposals of equal scientific and technical merit, chosen through the standard peer review process, it should make no difference to the agency whether that project is at one university or another.

We are at the phase where you start tossing proposals down the stairs. There is a gray area that people work in and try to be fair.

What we are proposing is that in this, after you make it through the first funnel, which is merit, the second funnel, which indicates that the results are likely to be commercialized, the third funnel should be designed to encourage access of R&D funds by those who may need them the most.

How can we do this? Among qualified proposals, awards should be made first to researchers located in schools in the bottom quartile of colleges and universities, ranked in terms of the Federal R&D dollars they receive. Since you have only got a limited pot of money, you give it first to the people whose schools are receiving the least amount of money. Next come people whose schools receive somewhat more money. And you work your way back up and hand out the money until it is all gone. These are the basic phase one funnels.

The phase two funnels work relatively similar. First you have got to make it through phase one. In phase one you prove the feasibility of your research, you show that something is likely to come out of it. If you do, you can go back for a second pot of money, up to $500,000 for two years, just like in SBIR.

And as in SBIR, we would use as a tie-breaking mechanism, after you made it through the merit and commercialization funnels, the additional tie-breaking mechanism of those proposals which have received firm commitments of follow-on funding will be given preference in their awards. Again you could hand out money to qualified proposals from poorest to richest.

The third phase would be non-Federal funds.

Now, the only other thing that would be different in this program that I have outlined, in comparison to SBIR, would be a recoupment mechanism.

NSF in a College and University Innovation program could use loans or a mix of grants and loans. People going into the program, would know they are applying to a program which uses loans. So there would be no surprises. If a researcher did not want to deal

with that, he or she could go through the regular program. But if he or she did want this kind of opportunity for very long-term money, then I think it is reasonable to ask them to pay back something as they are working on projects which may lead to commercially viable innovations. And that is precisely what the program would do.

Other than that, I would just note in passing that there should be an evaluation mechanism like SBIR.

Oh yes, we have run some numbers on recoupment periods to make the program self sustaining. We can show you, depending upon the funding levels, that you can recoup over 25 years, and have a self-supporting program.

That is less time than it takes to pay off your house mortgage, if you have got a 30 year mortgage. If you like the shorter house mortgage concept, we can show you a way make the program self supporting in 10 years.

To conclude, let me just simply note that if we were to go down this path and implement a College and University Innovation Research program, a CUIR to accompany SBIR, we do a couple of things.

One, we utilize a proven mechanism. SBIR has been studied upside-down and inside-out, and it is acknowledged to be a highly successful mechanism.

Two, we can test the recoupment mechanism through a pilot program. A CUIR, just like the SBIR could be first tested at NSF.

Third, faculty will have access to multi-year stable funding for projects beginning with basic research and ending with proof of viability of an innovation. And mechanism will exist to exploit breakthroughs like superconductors.

Fourth, Federal R&D investments will be leveraged by private sector dollars, and there is a substantial leverage, by the way, in SBIR. I have some numbers on that if you are interested.

Fifth, stronger ties will be built between university researchers and companies capable of commercializing the research results.

Sixth, tax revenues and jobs will be enhanced as new products and technology are commercialized.

Seventh, perhaps most importantly, a lot of very good and very important research will be done by faculty from both large and small and rich and poor schools.

Mr. Chairman, this is the first time that I have ever had the opportunity to come up here and testify on behalf of myself, and I thank you for the honor. I would like to say that if we work together, by the time that my son, who wants to be a scientist, (that comes from hanging around scientists I guess), by the time he is my age, if this program is in place, he will be able to apply for multi-year funding to do basic research from a small school in any state, and he would be able to have that research funded out of a program that was entirely self-sustaining. Thank you very much.

Senator EXON. Dr. Speser, thank you very much. Let me ask you a general question, because I do not begin to understand all of the complexities of science and different types of research and how this all works out.

We certainly are recognizing today that the Japanese are light years ahead of us in many areas when it comes to the development and production of goods and services. How do the Japanese do this? They must spend a great deal of money through their universities to develop some of the things that they have developed. Do they have, or what kind of a system do they explore or use or have been successful with to do what we are trying to do here?

Dr. SPESER. Well, I believe, sir, that, it is interesting. I am not an expert on Japanese science policy, I want to preface it with that.

But my impression is that the Japanese are in the process of rebuilding, in a sense, their university structure. They have emphasized often large cooperative projects, involving many companies.

And they have emphasized very heavy reliance on in-house programs. They also emphasize projects farther down of the scale. They traditionally have done less in the basic research area than us and much more in the developmental area.

I think one of the things that is interesting is the amount of interest that we have seen in this country from the Japanese as well as from the Germans and the Europeans in our SBIR program. That interest exists because what we did in the SBIR program was to establish a mechanism that had never been in place before anywhere in the world, we found a way to take advantage of the creative potential in small companies.

And that kind of mechanism, I think, can be applied to enable us to take advantage of the creative potential in our colleges and universities.

Senator EXON. Well certainly, Dr. Speser, the Small Business Innovation Research Program, which we call the SBIR, can be judged as a major success story, and we can all be proud of that.

In reviewing our Federal science programs I note no similar initiative available for small colleges or universities. And as you said, that is why we are trying to get into that area with the bill that I have introduced. And I thank you again for all the help you have been to us.

Could the SBIR format be used as a model for a program focused on small universities and colleges? And could a recapture element be included in this format, in your opinion?

Dr. SPESER. Yes, I think that in fact the unique thing about the SBIR program format is that the format is based upon a lot of good thinking and very close to what the scholarly literature shows on how to design a good R&D program.

The format is very simple. For example, you say, it does not make sense to give a lot of money to somebody and never review what they do. It does not make sense to give them a lot of money at one time and have no milestones to see if they are moving towards success. In industry you would not do that.

So what does SBIR do? SBIR has two phases. There is a milestone. You prove the feasibility, you get to that milestone, and then you recompete for the second pot of money.

That kind of a concept is used in the engineering research centers, for example. There is an evaluation three years out. The only distinction between SBIR and the engineering research centers is that in the engineering research center there is a phase-down period. If you get a negative review in SBIR, you do not even get to

compete for the second pot of money. There is no phase-down and no funding if you do not make it through the cut.

The phases concept is well established. Also established is the utility of funnels for leveraging R&D dollars.

So we have a good base of experience to build upon in designing a college and university innovation research program.

The one mechanism again that is not in SBIR is the concept of recoupment. But we have explored recoupment through the Federal Tech Transfer Act. That is a relatively young bill. So we do not have a lot of data about it. But I think that in the context of a pilot project, it is a very reasonable mechanism to utilize. And it is clear—I think certainly in talking with you and your colleagues on the Budget Committee it is hard to avoid it—that if we do not begin to explore new mechanisms for increasing funding for science as well as for spending money for science, in the long term we are going to constantly be faced with the kinds of ethical dilemmas that were discussed by the last panel. How do we do the tradeoffs?

We have to make the pie bigger in the long term as well as figure out better ways in dividing it up.

Senator EXON. You have been a very convincing advocate of this concept of establishing a self-supporting trust fund for science.

I believe that this could be one way to assure that science gets adequate funding in the era of tight Federal budgets.

What in your mind are the available devices, controversial or otherwise, which could be established to recapture Federal scientific investment and recirculated through the economy?

How long would it take to establish an adequate trust fund? I guess the obvious answer is, well, how much do you want to do? But I mean, what do you think would be reasonable and appropriate?

Could this concept be tested in the form of a pilot program with some initial funding of a somewhat limited amount by the Federal government? And would such a test have the support, in your opinion, of the general scientific community?

Dr. SPESER. I am just jotting down notes since it is a multiphased question.

Let me start with the question of mechanisms. There is a variety of recoupment mechanisms. In the industrial community, recoupment on projects being funded by the Federal government has been discussed for quite some time. I think I first ran into it about eight years ago in an article in Research Management.

The first obvious mechanism is to do something like tap into patent royalties. You can do that where the Federal Government owns the rights. It would not be appropriate where you have given the rights away. That would be a major shift in policy to tap into royalties.

The second mechanism is the mechanism that I am proposing here, is the loan. We use that all over the place in the Federal government, from agriculture to student aid. It is a well used mechanism and well understood.

And since we are not guaranteeing the loans here we do not have a lot of the kinds of concerns that might otherwise arise from a budgetary standpoint.

Other mechanisms include establishing a Congressionally-chartered private corporation and leveraging that way. For example, I believe in Great Britain they have explored the concept of putting some of the research results into pools and selling shares in the pools.

So there are a variety of other mechanisms that you can explore that, while they might not be appropriate for NSF, might work if you set the LUIR program up as an individual, Congressionally-chartered corporation like the National Trust for Historic Preservation or the National Institute of the Building Sciences. So there are a variety of other recoupment mechanisms as well.

In terms of the timing to get the payback, well that really does depend upon the amount of investment that you are looking at. We ran some numbers the other day. We ran two series of numbers, one for a 25-year self-sufficiency and one for a 10-year self-sufficiency.

On the 10-year plan at $40 million a year, this is larger than you may want to authorize, but this is just for the sake of illustration, $400 million would be put out over 10 years.

You bank the first $40 million at 5 percent, everything is 5 percent. Then you start only putting out money in phases and always banking a little of it. We bank the first year $40 million, the second year $30 million, after that $20 million. Then we are banking $14 million for the next remainder of the 10-year period.

You assume that 50 percent of the projects get cut out between phase one and phase two. They are just not technically viable. That is an SBIR, average that is pretty common across the government in SBIR.

You assume that you are giving out $500,000, $100,000 phase one, $400,000 phase two averages. You assume that roughly 40 percent of the phase two projects will only need to $200,000, the rest will need the full $400,000. And again, you assume 15 percent succeeds so they start paying back into the fund.

By the time you get to year 10, you can pull your $40 million out of the fund based upon the interest and the revenues coming back every year. And be self-sustaining.

Now, that is a relatively substantial amount of money to be laying out. I think that you could test the concept with a lower dollar sum and still a 10-year authorization and examine, you know, if the basic parameters are sound. But you have to be able to put enough money out for projects in order to get a spread in the sense of the results coming in.

It is like in a venture capital industry. You do not assume that every project is going to hit, but you assume that enough in the portfolio will. So you have to have enough money out in order to develop that spread. So in terms of timing, it really does depend upon what you want to put in.

In terms of running it as a pilot project, I think that is precisely what is called for. SBIR was, as you may be aware, developed that way. Even the legislation had a sunset in it so it would be reviewed. And I think that would be an appropriate approach.

In terms of support, I guess the best way to put it in terms of support is I would encourage you and any member of this Commit-

tee to go back to your state and start talking to the faculty at your schools.

Ask them, "If there was a program for you to tap into this kind of stuff, would you be interested in it?" And I would be very surprised if, particularly as you spoke with people who were not in the major departments of major universities, if you did not find a lot of enthusiasm. Because it is very hard to get research funds nowadays.

I think that you would find substantial support and I think you would also find substantial support from two other sectors. The business sector, which has been highly enthusiastic about SBIR, and also from your state governments. You may be aware most state governments have developed programs, economic development programs, leveraging the Federal SBIR program.

The proposal that we have been discussing today is modeled on SBIR, also from the standpoint of economic development. So you should see a lot of enthusiasm in the business community, both large and small, and in the economic development communities within the states.

I am pretty comfortable also that the faculty would be quite enthusiastic about it, based on my discussions with friends. The best way I can point that out to you is to give you the following example.

I came down here after teaching a while, and I decided not to pursue a career in the university. My best friend still teaches from graduate school. He teaches in a small college outside of Amherst, Massachusetts.

He makes around $30,000 a year, including his research money. He cannot compete for SBIR funds if he has a good idea. He does not get travel money from his university if he wants to build a center, because he is in a college. They do not have travel money like that.

So he is at a disadvantage when it comes to competing for multiyear money. Would Harry be interested in having an opportunity to compete for something, even if he had to pay it back? Of course he would. There is no other real source of funds that he can tap into other than the narrow disciplinary programs inside NSF. So of course, they would be quite enthusiastic about it.

Senator EXON. Well, thank you. You have partially covered the last question that I was going to ask you, because that is the $64 question, I think, as far as what we are trying to do with this program.

I think generally speaking we have had a successful program, and that is why I have supported science and research.

The first time I became interested in a program like this was when I went out and visited with the faculty of our science department at the University of Nebraska.

We are one of the basic have-not schools, although we are a very large and well thought of educational institution. And it was there that I realized the keen competition that there was for these Federal funds, and that, as you know, the Harvards and the MITs and the Stanfords and the Columbias do well because they have traditionally done well.

But I was never very certain that that money was spread evenly around. It was more or less a situation where the rich get richer and the poor get no richer and probably a little bit poorer.

You then basically think that if we could get a program like this started, and based upon this program that you have been so outspokenly successful with, then you think that is probably one way that we could at least begin to assure that the pilot program works, that the resources of science and technology get spread around a little bit more to schools like your best friend, and Nebraska, and others similarly situated all over the country?

Dr. SPESER. Yes, absolutely. And I would add one thing, or two things. Number one, again I want to emphasize that by adopting the SBIR structure, the first cut is always on scientific and technical merit through the same NSF peer review panel. So we are not deviating from quality.

I personally could not support a program that sort of threw quality aside, because after all NSF is a basic science funding agency, and you want to fund good science. It does not help any of us to fund bad science. But once we are through that threshold, then we can meet other objectives.

The only other thought that I would leave with you, sir, is I want to also emphasize that while it would be my hope that faculty in schools that have not traditionally done well competing for Federal R&D funds, do quite well in this program, others would also benefit.

This program would also mean a lot, for example, to a faculty member at Harvard whose department was not one of the key departments that they were building at that time. So he or she might not have the same access to travel funds.

This is not a program that pits big schools against small schools. This is a program designed to enable faculty to get additional research dollars. And that, I think, is an important feature of it.

Senator EXON. I cannot thank you enough for coming here and being with us this morning. And we appreciate your valuable input.

And I encourage and ask you to keep working with us on this as we refine this bill that we hope will lead in the near future to a pilot project of some kind, so we can maybe do a little science work on our own with regard to legislation and see if it works.

Good luck to you and your son on your contraption there. I was very, very much interested in it. And that is great training for that young son of yours. Thank you for coming, and we are adjourned.

[Whereupon, at 1:00 p.m., the hearing was adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF THE AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

Mr. Chairman and members of the subcommittee, the American Association of Engineering Societies (AAES) is a multidisciplinary organization of engineering societies dedicated to advancing the knowledge, understanding, and practice of engineering in the public interest. The member societies of AAES, which represent over a half million engineers in industry, government, and education, include:

American Society of Civil Engineers
American Institute of Mining, Metallurgical and Petroleum Engineers
American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
American Society for Engineering Education
American Institute of Chemical Engineers
National Institute of Ceramic Engineers
Institute of Industrial Engineers
Society of Women Engineers
Society of Fire Protection Engineers
American Institute of Plant Engineers
American Nuclear Society
American Indian Science and Engineering Society

AAES endorses the NSF budget request for fiscal year 1989 of $2.05 billion. This request, which is a 19 percent incease over FY 1988, is an important step forward in NSF's effort to strengthen its research and development activity and is part of a long-term, sustained move toward improving its base for education and university basic research. AAES supports these measures.

INTRODUCTION

The NSF mandate in engineering is divided among three directorates: Engineering, Computer and Information Science and Engineering, and Science and Engineering Education. Each of these directorates is important to the nation's engineering enterprise, and we are pleased that in its budget request the Foundation has recognized the vital role of engineering education and research in strengthening U.S. economic competitiveness and quality of life. It is the educational and research opportunities presently open to our young engineers today that will allow the United States to meet the challenge of high technology in the twenty-first century.

Before discussing the specifics of the NSF budget, it is important to define the nature of engineering research. Engineering research is the pursuit of new knowledge about the technical processes and systems of the man-made world. It is closely related to scientific research, which seeks to understand the fundamental theories and systems of the natural world. While engineering research uses the foundation of scientific knowledge about the natural world, it has its own rules and laws and takes into account factors beyond science such as economics, aesthetics, and law.

Engineering and scientific research, while distinguishable, are mutually supportive in important ways. Information uncovered in the process of scientific research can lead to solutions to problems in engineering research, while advances in engineering stimulate scientific research.

Like scientific research, engineering research can be characterized as both "basic" and "applied." Basic engineering research seeks to provide a theoretical foundation for engineering principles and applications. For example, although ironmaking has been known for sixty centuries, only recently have the complex scientific and engineering principles underlying this process been revealed. While the ancient metalsmith could improve his craftsmanship through experience and trial and error, he lacked the knowledge of thermodynamics, heat transfer, and fluid mechanics that would have enabled him to guide his experimentation.

Applied engineering research builds on basic research, both in engineering and science, to find answers to specifc technical problems. Applied engineering research may be viewed as the link between basic engineering and the development of new

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or improved products and services. Applied engineering research employs basic research in metallurgy to develop steel alloys to meet prescribed specifications. Applied engineering research is nearly always cross-disciplinary: in trying to solve engineering problems, it draws heavily upon knowledge developed in several engineering and scientific disciplines.

THE ENGINEERING DIRECTORATE

The work supported by the Engineering Directorate—both basic and applied engineering—is the foundation of technological advances in computers, communications, manufacturing processes, and space technology, all areas that are vital to the nation's productivity and economic well-being. As more than half of the gains in U.S. productivity since World War II are the result of technological innovation, engineering research is clearly essential to further productivity gains.

We support the Administration's proposal to increase the budget of the Engineering Directorate by 13.7 percent in FY 1989, to $195 million. In recent years, the U.S. has been losing ground to its competitors. One contributing factor was the reduced emphasis on engineering research during the 1970s. The U.S. is now fourth among industrial countries—behind Japan, West Germany, and France—in the portion of gross national product invested in civilian research and development.

The multidisciplinary Engineering Research Centers (ERCs) merit continued strong support. While it is yet too early to gauge all the benefits that will come from the ERCs, they have already prompted significant intellectual activity, financial commitment, and cooperation in the academic community and gained strong financial support from industry. These centers reflect the trend toward interdisciplinary collaboration in addressing complex and urgent problems. They also provide unique opportunities for education and technology transfer. We believe that many exciting projects being developed through the ERCs could lead to major breakthroughs in telecommunications, robotics, biotechnology, and the development of composite materials.

While we approve the administration's emphasis on programs to enhance the nation's competitive position in world markets, we believe it is also important that NSF maintain its traditionally strong support for its basic engineering programs that support individual principal investigators involved with engineering research that is important for the long term vitality of engineering. Several engineering disciplines rely heavily on NSF grants for engineering research. In FY 1986, NSF supported 77 percent of all federally sponsored civil engineering research and 74 percent of all federal research in chemical engineering at universities and colleges. More importantly, NSF is the only agency whose purpose is to support both basic and applied long-term engineering research across all fields. This includes areas that may not appear to have immediate technological payoffs but may lead to breakthroughs in the future.

THE COMPUTER AND INFORMATION SCIENCE AND ENGINEERING DIRECTORATE

Because of their revolutionary impact on communications and information processing, computers have changed the conduct of science and engineering in a host of ways; from modifying methods of research and redefining the meaning of state-of-the-art procedures, to reshaping the ways in which students are taught in the classroom and participate in laboratory practice. Thus, continued progress in computer science and engineering is vital not only for the development of newer, more sophisticated computers and applications but as a key element in other engineering disciplines.

AAES supports the Foundation's proposed 20.3 percent increase in the Computer and Information Science and Engineering Directorate budget to $149 million for FY 1989. We also support NSF's two-pronged initiative to support research into the fundamental understanding of computer and information science and engineering and to expand the availability of advanced computing systems and encourage participation in their use.

THE SCIENCE AND ENGINEERING EDUCATION DIRECTORATE

Fundamental to engineering and computer research is engineering education. Without talented and well-educated individuals conducting first-rate research projects and teaching young engineers, the system will falter. For that reason, AAES strongly supports the expansion of educational and human resources programs envisioned by the Foundation.

Continued support for NSF precollege mathematics and science programs is vital. Our high school graduates must be well-prepared and highly motivated or the nation will soon face a serious shortage of engineers and scientists to meet the ever more demanding needs of government, industry, and academia. Over the past several years, NSF has considerably upgraded its precollege activities and we support NSF's role in this area.

Of special significance the engineering community is the Foundation's initiative in undergraduate education. In the 1970s and early 1980s, undergraduate education was barely addressed at the Foundation. However, since FY 87 NSF has begun to redress this imbalance and this year plans to spend up to $65 million on undergraduate education. The measures the Foundation has initiated are designed to improve undergraduate engineering curricula and faculty development, as well as expand educational instrumentation and undergraduate research programs. Unlike the physical and life sciences where most practitioners in the field are required to have advanced degrees, more than two-thirds of the nation's 1.5 million engineers have received only a bachelors degree. Their four years of college education provide an essential basis for professional development programs throughout their careers.

NSF support for undergraduate engineering education also serves as a catalyst for colleges and universities to revitalize their curricula and to modernize engineering laboratories. Programs to foster experimentation in faculty development permit faculty members to update their technical knowledge and enhance their teaching skills. Greater undergraduate participation in research exposes students to the benefits of an academic career.

Expansion of graduate programs at NSF forms another key link in the system. The NSF has maintained its graduate fellowship programs over the past several years. Creation of one hundred additional graduate fellowships and two hundred new Presidential Young Investigator awards are the types of incentives that will encourage promising young graduate students to remain in academia and join the ranks of permanent faculty.

In addition to these measures, support for undergraduate and graduate education is carried out indirectly through Foundation funding for research projects. For example, most of the nearly 15,000 NSF-supported graduate students and research assistants are funded through faculty research grants.

SUMMARY

Overall, we in the engineering community support the major outlines of the FY 1989 budget for the National Science Foundation and praise the Foundation's strong commitment to engineering and scientific research and education. Accordingly, we urge the Congress to carry through with substantial increases in the Foundation's budget over the next several years. This increase will help NSF balance its support for programs that foster economic vitality with those that ensure the long-term health of basic engineering research. It can make a real contribution to the nation's economic well-being.

We appreciate the opportunity to represent AAES' views on the FY 89 National Science Foundation budget.

STATEMENT OF THE ENGINEERING EDUCATION TASK FORCE

Mr. Chairman, we appreciate this opportunity to share our views on the National Science Foundation budget for Fiscal Year 1989. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society group working together to address major issues in engineering research and education. Member organizations are the American Society for Engineering Education (ASEE) and its Engineering Deans Council, the National Society of Professional Engineers (NSPE) and the National Association of State Universities and Land Grant Colleges (NASULGC).

ASEE is a membership society of more than 10,000 individual members as well as schools of engineering and engineering technology and engineering-oriented industrial companies. NSPE is a professional society representing 75,000 professional engineers in industry, construction, private practice, government, and education. NASULGC is a higher education association whose member public colleges and universities educate more than two million of the nation's students each year.

The Engineering Education Task Force believes the increases in education and engineering research proposed in the FY 1989 NSF budget are inadequate; the need is considerably greater. As our economic competitiveness and quality of life become increasingly dependent on technological advancement, we must strengthen our invest-

ment in technological education and research. It is the high quality education and research achievements of young engineers and scientists today that will lead the nation into the high technology future of the 21st century. Moreover, with technology tightly linked to political and economic decisions, our nation's citizens must achieve greater technological literacy.

The National Science Foundation's role in this effort is not only to support basic research and education, but to provide national leadership and leverage resources from industry, state and local governments and academic institutions in addressing these challenges.

ENGINEERING RESEARCH

Members of the task force believe that engineering research in NSF historically has been underfunded. The proposed increase for FY 1989 fails to continue the previously proposed and broadly supported plan to correct this deficiency. A request for the engineering directorate of $10 million less than last year's request is not persuasive evidence of commitment to this goal.

The inadequacy of the proposed funding is illustrated in the NSF's Engineering Research Centers (ERC) program. The academic and industrial communities have overwhelmingly proved they are capable of working together in industrially-relevant research, updating engineering curricula and transferring technology from engineering schools to cooperating industrial companies.

Rather than recognizing the successes of this experiment in academic engineering research and education, NSF has slowed development considerably. Two new centers for FY 1988 have yet to be designated and the Foundation is proposing only two new centers for FY 1989. This total of 18 centers is well below the 25 centers recommended in the original National Academy of Engineering proposal. This is particularly unfortunate in light of the fact there are superb technical proposals that are not being funded.

THE STUDENT PIPELINE

We would like to focus our remarks on the greatest long-term challenge to engineering education: the student pipeline. As you know, between now and the 21st century, the nation's college age population will drop by 25% and become increasingly Black and Hispanic, groups which have traditionally been underrepresented among engineering students. This demographic fact is particularly important to engineering because unlike many other fields, most engineering students are full-time, of traditional college age. Moreover, recent gains in attracting nontraditional students to engineering have begun to lag. Although the number of women engineering graduates rose by ten-fold and the number of underrepresented minority engineering graduates tripled between 1975 and 1985, since then those numbers have been dropping. If we are to maintain our engineering workforce, we must find stronger means to attract these students into engineering.

Given the seriousness of this challenge, the ASEE Engineering Deans Council, which is comprised of the deans of accredited U.S. engineering schools, earlier this year organized a task force, funded with an NSF grant, to examine what the deans of engineering could do individually and collectively to open up the engineering student pipeline. Among their recommendations, the deans agreed they should join or form regional consortia whose goals are to increase the numbers of minority and women graduates in engineering, and should re-focus the engineering school environment from one that "weeds out" the less-prepared students to one that identifies and nurtures a broad range of students. The deans also agreed they should set for themselves specific goals for recruiting and retaining underrepresented students. ASEE will soon make available to you a full copy of the deans' report and recommendations.

NSF has recognized the growing challenges of the engineering and scientific student pipeline and we endorse its increasing investment in addressing these issues through both the education and research directorates.

PRECOLLEGE

At the precollege level, the Foundation supports a number of high-leverage activities designed not only to engage early-on those students who may become engineers and scientists, but to raise the technological literacy of all Americans. We strongly support these programs in teacher training, classroom materials development and informal education, and applaud the strong Congressional leadership in this area.

NSF has been supportive of such efforts as the Junior Engineering Technical Society (JETS) sponsored jointly by NSPE and ASEE.

UNDERGRADUATE EDUCATION.

A key section of the student pipeline for engineering is undergraduate education. In contrast to the sciences where the principal point of entry into the profession is the doctorate, about 70 percent of all engineers begin their careers with a baccalaureate degree. This makes it particularly critical that undergraduate engineering education be an up-to-date and effective educational experience.

Since the 1970's, undergraduate education—the vital bridge between high school and professional careers or graduate study—has been sorely neglected at the Foundation. In response to a 1986 report of the National Science Board, however, the Foundation has reintroduced support for undergraduate programs. While FY 1988 funding has been less than expected, we commend the agency for systematically reintroducing undergraduate activities and creating a new office of undergraduate education in the education directorate to coordinate Foundation-wide efforts. For FY 1989, NSF proposes spending about $65 million on undergraduate education and research, about two-thirds of which will be funded through the research directorates. This will support research opportunities for undergraduate students, women and miniorites, instrumentation for the improvement of undergraduate teaching.

We strongly endorse these activities and believe NSF could effectively spend more than the $100 million per year on undergraduate activities recommended by the National Science Board report. There are two areas in particular we believe would benefit in FY 1989 from enhanced investment. Major curriculum revitalization projects were initiated in FY 1988 by NSF for both calculus and engineering. For calculus, this effort was recognition of the fact that as the basis for all physical sciences, the calculus curriculum needed to be updated. For engineering, it was recognition that with the rapidly changing nature of engineering practice and the impact of new instructional technologies, new approaches were needed in the undergraduate curriculum.

Although NSF had proposed spending $6 million on these programs in FY 1988, budget limitation reduced actual spending by half, to $3 million. The Foundation proposes to spend only $4 million for all curriculum revitialization in FY 1989. In light of the strong response NSF is already receiving from the academic engineering community alone, as well as the importance of systematically introducing new materials and methods into engineering and scientific curricula, we believe significant funding above the $4 million request would be a valuable investment.

At the same time, technological change has been so rapid in recent years that many engineering faculty cannot keep up with developments outside their own areas of expertise. NSF-supported experimental short courses and conferences will colleagues in industrial and academic research can enable faculty to catch up on technological developments and incorporate them into their teaching. Once again, we believe that funding above the $3 million request for faculty professional development would be an important investment.

OTHER STUDENT PIPELINE ACTIVITIES

An area of great importance in NSF's program in the education directorate to create regional centers in which minority students would be tracked and nurtured in mathematics, science and engineering from elementary school through college. We believe this program has significant potential for addressing the varied factors that limit entry of underrepresented minorities into engineering and scientific careers. We also commend the Foundation for its initiatives in promoting research opportunities for women, minorities and the disabled. These program help create the role models that are vital for increasing the flow in the student in the student pipeline.

GRADUATE EDUCATION

One of the biggest challenges facing engineering education is attracting greater numbers of U.S. students to engineering faculty careers. According to a recent report by the National Academy of Engineering (NAE), nearly 50 percent of all engineering assistant professors age 35 years or younger are foreign-born.

The failure to attract U.S. students into engineering faculty careers is a result of several factors, including the availability of jobs in industry for BS graduates at salaries that make graduate study relatively unattractive. However, we believe prestigious NSF fellowships and research opportunities offer useful incentives for the

brightest students to consider academic engineering careers. We strongly endorse the Foundation's plan to increase the number of Presidential Young Investigator awards and graduate research fellowships in FY 1989. We also believe that graduate fellowship stipends should be increased for fields such as engineering and computer science where market forces keep baccalaureate salary levels high.

We also recognize the importance to the academic pipeline of NSF research grants. Only 12 percent of the graduate students supported by NSF participate in the graduate research fellowship program. Most of the nearly 15,000 NSF-supported graduate students are research assistants funded through faculty research grants.

If we hope to attract more U.S. students to academic engineering careers, additional steps must be taken to remove financial barriers to graduate study. Federal grant stipends should be raised to equal one-half the average starting salary of an engineering graduate. For NSF, that would mean raising graduate research fellowship stipends in engineering from $21,000 to about $15,000. At the same time, full tax deductibility should be restored for both graduate student stipends and tuition remission. To attract more students into faculty teaching careers, the federal government should consider offering forgiveness on student loans to those who undertake careers in teaching.

SUMMARY

Through the Foundation's role as a catalyst for academic activity and its ability to leverage resources, we believe NSF programs can make a significant difference in promoting the nation's economic well-being. By helping educate the engineers and scientists who will keep us at the forefront of technological achievement and competitiveness and by sponsoring cutting-edge research and technology transfer, NSF is contributing directly to the nation's engineering and scientific strength.

The Engineering Education Task Force supports substantial increases in NSF research funding for FY 1989, particularly in engineering research. We also urge you to consider increases above the budget request for faculty development and curriculum revitalization programs. We believe the Foundation's education and research programs represent a sound investment that will benefit the nation for decades to come.

STATEMENT OF DR. JOSEPH A. SALOOM ON BEHALF OF THE COUNCIL ON RESEARCH AND TECHNOLOGY—CORETECH

On behalf of CORETECH, the Council On Research and Technology, we would like to be able to submit this statement for the hearing record.

CORETECH was formed to link the interests of the corporate and academic research communities. To date, CORETECH includes 79 universities, 44 corporations, 7 research institutes, 16 associations, and 7 affiliates for a current membership of 153. We are still growing.

THE INDUSTRY STAKE UNIVERSITY RESEARCH FACILITIES

It might seem unusual to some that industry wants to go on record with the university community in favor of rebuilding, repairing, and replacing academic research facilities. But our stakes in doing so are high.

Few U.S. corporations have the resources to conduct long-term, basic research. Yet we depend on scientific achievement for our future products.

We look to universities not just for basic research but also for our engineers, scientists, and other skilled personnel. We have entered a knowledge-driven global economic age and our need for state-of-the-art students trained in state-of-the-art facilities will only increase. To the extent that our universities are inadequately staffed, to the extent that students are inadequately prepared, and to the extent that their work must take place in inadequate facilities, then we all suffer.

SUPPORT FOR THE UNVERSITY FACILITIES PROGRAM

CORETECH members enthusiastically support revitalizing the university research facilities. We endorse this program for the very same reason that the industry and academic research communities formed CORETECH. That is, the belief that how we get from basic research to job creation is not a set of isolated events but is instead a continuum. Research, development, commercial application, and jobs are integral parts of a continuum that in large part determine whether we will, or will not, be competitive in world trade.

By viewing the path to competitiveness as a continuum, we can see that today's success depends on policies adopted years ago. Dr. Paul Chu of the University of Houston, for example, has been doing fundamental investigations into superconductivity for 15 years. Now, his work and the work of other scientists in superconductivity appear to be near fruition.

Fifteen years from now, in the year 2003, if we want to continue to achieve major sacientific breakthroughs, we need to invest in basic research today.

EXPERTS NOW RECOGNIZE CONTINUUM

The continuum from fundamental inquiry to economic growth is only recently being widely acknowledged. Economists are now reporting that at least half of the phenomenal productivity growth achieved since World War II was due to technological innovation.

It is no accident that this period of rapid growth coincided with the rise of research universities. Prior to the surge in federal funding for university research that began in the late 1940s and early 1950s and accelerated after Sputnik, the United States did not have a commanding lead in science. For example, from 1901 to 1941, the first 40 years of Nobel Prizes, only 17 Americans received these awards for science. In the four decades following World War II, Americans received 117 Nobel Prizes in science.

There are undoubtedly many reasons why U.S. scientists have excelled in the second part of this century. Chief among them has to be the unique coupling of research and advanced study that American universities foster. Over half of our basic research is now conducted in universities.

COMPETITIVENESS AND THE RESEARCH CONTINUUM

The seeds of our scientific success were clearly sown the two decades following World War II. It is also now clear that the sources of our current concerns over lagging productivity growth and our trade deficit can be traced to the period following this post war surge.

A few statistics point to where these problems began:

1. Following the surge in federal spending on scientific research in the 1950s and 1960s, federal aid of university research went through a long period of stagnation in the 1970s. Private, industrial R&D spending, I might add, also showed no growth for most of this period.

2. Federal support of university research physical plant dropped 95% in real terms over the past two decades. As a result, it is now well documented and widely acknowledged that university research facilities are all too often obsolete, inadequate or inappropriate for advanced work.

3. Corporate support fell from about 8% of university research funds in 1960 to about half that proportion in the late 1970s. There were no federal incentives to encourage cooperative company/university research until very recently.

U.S. RESEARCH COMMUNITY AT A CRITICAL JUNCTURE

Years of stagnation and neglect have begun to take their toll. We are now at a critical juncture with regard to the U.S. research community.

On the positive side, there are signs that public policy has begun to recognize the critical role of research and development in our economy. Let me cite a few recent examples.

Congress adopted an enhanced incentive for corporate donations of scientific equipment to universities for research and research training. Industry has responded to this incentive and many of our academic laboratories now boast state-of-the-art equipment and instrumentation. I might add, however, that it does little good to receive state-of-the-art equipment if your buildings are too old to handle it.

Congress adopted the R&D tax credit which, economists say, raised R&D spending by about 7 percent a year, including increased spending for research conducted under contract by universities.

In 1986, Congress adopted the basic research credit to encourage company support of basic research at universities and nonprofit research institutes. The underlying public policy of this new credit was recognition of the importance of encouraging greater linkage between academic research and corporate research.

Experts say that probably the single most important thing you can do to accelerate the commercial application of new ideas is to improve the cooperative working relationships between university and company researchers. As the recent discussion

surrounding the superconductivity findings have shown, we are not just in a race to discover, but we are also in a race to commercially apply the new research.

We commend Congress for these positive steps but we caution that they are only a beginning.

FEDERAL SUPPORT ESSENTIAL

In 1986, the White House Science Council stated: "Our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support. CORETECH agrees completely with the White House Science Council's statement. Some of the increased support will come from industry. In part because of government incentives, industry support of university basic research tripled over the past several years. And this trend should continue. However, industry support is under 6 percent of all university scientific and engineering research. Even continuing increases in corporate contributions will not be enough to meet the real needs.

The predomiant responsibility for supporting university research has been, and must continue to be, the Federal Government. The White House Science Council stated "the federal government must take the lead . . ." we agree. The rewards from basic research, by their very nature, benefit society in general. Just as the rewards from basic research are widely shared by all of us, so too must the cost of such research be borne by society.

Advanced research of the type we expect our universities to perform almost always requires sophisticated equipment and specially designed facilities. If we want our academic institutions to continue to perform advanced work, then we must support them. The White House Science Council estimated that, to make up for past neglect and to bring our university research infrastructure up to speed over the next 10 years, the Federal Government should spend $5 billion and non-Federal scources should match that figure dollar-for-dollar. In view of fiscal realities, we support the more modest but nonetheless realistic authorizations in S. 1632.

CONCLUSION

We hope that congress is fully aware that university research is vital to corporations and our society. It is also fragile. It is something we cannot leave to others. Years of neglect and stagnant or declining support have brought the university research community to the point where its facilities can no longer house enough of the kinds of advanced research or attract and keep enough of the first-rate faculty members we need to stay ahead. This committee, we hope, will act favorably and quickly.

We would like to add that nonprofit independent research institutes also perform a significant part of our nation's basic research and are also involved in the research training of graduate students. We respectfully request that these charitable institutes be included as eligible institutions.

Many of us in industry research and development are enthusiastic about our growing and promising relationship with the academic community. We hope that by working more closely together, the time between the discovery of a new idea and its successful commercial application will be shortened and improved. We in industry are investing more in basic research. We in industry are trying to help upgrade university laboratoy equipment and instrumentation. But the Federal Government must take the leading role in upgrading facilities to house the advanced research, the new equipment, and most importantly, the talent that will drive our Nation's competitiveness in the years ahead. We urge the committee to act on this legislation expeditiously.

IEEE WASHINGTON OFFICE
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.
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Statement of the Institute of Electrical and Electronics Engineers, Inc.
On The
FY 1989 Budget of the National Science Foundation
Before the Subcommittee on Science, Technology and Space
Senate Commerce, Science & Transportation Committee
May 17, 1988

It is a pleasure to submit the views of the Institute of Electrical and Electronics Engineers (IEEE) on the proposed budget for the National Science Foundation (NSF) for Fiscal Year 1989. The IEEE is the world's largest technical professional society, with some 232,000 members in the United States alone. Our membership consists primarily of engineers and scientists in the electrical, computer and communications disciplines, so we have a very great interest in the programs of the NSF.

Today, the United States economy faces the greatest competition from offshore manufacturing than any time since the 1930's. This is largely a result of other nations rebuilding formidable post-war industrial capacities, and often employing technologies that were originally developed in the United States to drive us out of both foreign, as well as our own domestic, marketplaces. To a large extent, the ability of the United States to forestall further erosion of our economic well-being will relate to our ability to prepare the next generation of highly skilled technical manpower, and our ability to set a rapid pace of technological innovation well beyond that of our economic competitors. We believe that the NSF will play an essential role in this mission.

Although this is necessarily a time of austere funding for Federal programs, we believe that the NSF's budget represents the "seedcorn" from which the U.S. economy can grow, by advancing our national human technical base in science and technology. Thus we feel that the Administration is fully justified in proposing $2.05 Billion for the NSF, an increase of 19% as part of the overall plan to double the NSF budget in a five-year period. We see these requests as recognition of the key role played by basic research and engineering education in the health of the U.S. economy and our competitive posture internationally.

We fully concur with the proposal to broaden the earlier NSF initiatives on Engineering Research Centers to include Science and Technology Centers, particularly in Computer and Information Sciences and in Material Sciences and Engineering. The proposed new research programs in materials processes and interfaces, cognitive science and architecture, large scale systems engineering, and supercomputer applications are excellent choices as areas that have great potential impact on the future productivity and competitiveness of the nation.

As we have expressed in previous testimony, we recommend an approach which balances support for such centers with support for individual investigators in disciplinary programs, and thus, also balances support for basic and applied research. Thus we also strongly support the proposal to increase the average grant size to individual investigators, largely to correct the decline in real dollars for support of graduate students during the last ten years, and the equally important proposal to increase substantially the funding of Engineering Research Centers, so as to permit these exemplary units to function as originally envisioned. We would like to see further attention paid in future years to basic research in areas, such as telecommunications, which have not received significant increases to date.

With respect to the two general styles for supporting research activities, through centers on the one hand and individual investigators on the other, we recommend that a third approach between these two extremes should also be employed by the NSF. Because of the magnitude of funding necessary for research centers, very few can be funded. On the other hand, there are many engineering schools of small to medium size across the country, which taken together, contribute a large fraction of the total number of engineering graduates in the United States each year. There is an urgent need to harness this important national resource, if we are to maximize U.S. industrial competitiveness. It is not feasible to operate centers at most of these schools, although many of them have first-class faculty investigators. We suggest that the NSF consider the possibility of initiating a program to support research teams which would not necessarily be either large or cross-disciplinary. Although such teams could, in principle, be supported through either the centers program or the disciplinary programs, it is in fact extremely difficult to compare small group efforts with the other categories. The review process for either of the existing categories tends to eliminate efforts involving three to five investigators. They are clearly too small to qualify as centers, and Disciplinary Program Managers tend to break small team proposals into parts for separate review, which eliminates the synergism available through group efforts.

We would also like to point out that shorter-term, goal oriented research would be one particularly fruitful way of applying such smaller group grants, which could maximize their beneficial impact on productivity in U.S. science and technology. A great deal has been said and written recently about the relatively short-term focus of U.S. industry, which contrasts sharply with the long-term focus of academia. we observe that scientists and engineers from these two critical resource groups in our country are frequently most productive when working together, sharing a focus that is long enough for the results to be competitive internationally, but short enough to give a high likelihood of productive results. Government has had the wisdom to sponsor some such efforts. The NSF Centers are an example, on a larger scale; work sponsored by the Defense Advanced Research Projects Agency (DARPA) is another. DARPA sponsors a full range of team sizes, and in many cases insists on cooperative university-industry efforts in order to bring together the best of theory and practice.

We would like to encourage the NSF to provide grants to small teams of academics, including some for the purpose of working cooperatively with industry. We believe that engineering faculty members would particularly benefit from the practical experience gained in such work. At the same time a much-needed influence would be applied to U.S. industries, drawing them toward products and manufacturing methods more advanced than their current short planning horizon allows. This approach is consistent with the forward-looking management of research funding which we associate with the NSF, and hope to see it implemented under an expanding budget for the Foundation.

In summary, we support the NSF budget with the recommendation that the NSF fund small groups of researchers in intermediate sized centers. We feel strongly that our nation should maintain a position of world leadership in the development of science and technology. These agencies are keys to achieving this goal. The few tenths of one percent of our federal budget that are needed to achieve that leadership will be recovered many fold in the prosperity that will result from this investment in our future.

STATEMENT OF HOWARD J. SILVER, PH.D., ACTING EXECUTIVE DIRECTOR, CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS (COSSA)

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral science disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Member associations, Affiliate societies, and Contributor institutions is attached.

COSSA would like to take this opportunity to express its appreciation for this Committee's past strong support for the social and behavioral science disciplines at the National Science Foundation. What follows are comments on the proposed FY 1989 budget for the NSF and some of the issues raised by that budget.

We strongly support the proposed overall increase of 19.4% in the FY 1989 budget and the continued commitment to doubling the Foundation's resources. The $333 million increase represents an incremental step for investing in the future greatness of this nation. In this era of budgetary restraint, the administration's advocacy of increased support for America's scientific endeavors reflects an understanding that more basic research today means greater scientific and technological achievement tomorrow. Reducing that commitment will decrease the nation's ability to compete in the interdependent world of the Twenty-first century. We urge the Congress to accept the full NSF increase.

The 10% increase for Research and Related Activities is also welcome. We strongly urge the maintenance of that increase during the Committee's deliberations. The 8% increase for the Social and Economic Science Division and the 6% increase for the behavioral programs of the Behavioral and Neural Sciences Division, while not as large as necessary, reflect continued NSF support for these programs.

A recent report of the National Research Council, The Behavioral and Social Sciences: Achievements and Opportunities, notes that the decline of federal support for these disciplines in the last fifteen years has been 25% in constant dollars. By contrast, during the same period, federal support for other fields of scientific research has grown by 36%. Funding for the National Science Foundation has increased significantly in the past eight years, yet the share of those funds going to social and behavioral science research has continued to decrease (from 6.1% in FY 1980 to 4% in the proposed FY 1989 budget). In calling for new federal funding of $240 million for the social and behavioral sciences, the report asks that NSF contribute $60 million. Spread over three years and including support for new fellowships, this request could be met by increasing funding so that 5% of the FY 1989 Research and Related Activities budget goes to social and behavioral science research. This would mean adding $16 million to the FY 1989 proposed funding in these disciplines. We believe this is a justifiable goal given the intellectual vitality and ferment of these sciences and their importance to the nation.

The NRC report presents a significant picture of the

vitality, ferment, and contributions of these disciplines. Although meant to be illustrative and not exhaustive, the report identifies five fundamental areas where researchers face extraordinary challenges and opportunities to develop their work in multidisciplinary fields and activities if they are given sufficient support. These areas include:

1) research linking behavior, the mind, and brain focusing on seeing and hearing, memory, cognition, decision making, and language acquisition;
2) research on the motivational and social contexts of behavior focusing on affect and motivation, health and behavior, crime and violence, and social interaction;
3) research on choice and allocation looking at agenda setting, voting behavior, organizational design and change, markets and economic systems, bargaining and negotiation, and jobs, wages, and careers;
4) research on institutions and cultures, investigating the evolution of human society, demographic behavior, family and religion, science, technology, and public policy, internationalization, and international conflict; and
5) research to improve the methods of collecting and analyzing data, examining data collection designs, formal models, and statistical inference and analysis.

All of these would benefit from increased interdisciplinary cooperation and increased federal support.

The proposed FY 1989 NSF budget for the social and behavioral sciences further reflects the emphasis on multi-disciplinary activity. The new National Center for Geographic Information and Analysis (NCGIA) will provide greater access to the products of digital remote sensing, geographic information systems, computer cartography, and computer graphics, which will form the basis for major advances in geographical analysis, spatial statistics, and expert systems. The enhanced information-portrayal and decision making capacities resulting from such theoretical advances will enable scientists and policy makers more effectively to resolve the complex environmental and social issues the nation faces now and in the future. This center will involve expertise in disciplines including geography, information science, computer graphics, political science, remote sensing, risk analysis and many others. Commercial vendors, government agencies, and research universities will share in the services that will be provided by the NCGIA.

The Decision, Risk, and Management Science Program (DRMS) will continue to strengthen its efforts to encourage collaborative interdisciplinary research across the decision sciences. Three broad problem areas remain the focus for exploration: 1) risk perception, communication, and management; 2) group decision making; and 3) artificial intelligence approaches to problem structuring and model building for decision support. Here too the number of disciplines involved is large: from artificial intelligence and expert systems to political

science, psychology, and sociology to organization design and general systems theory.

In the behavioral sciences the major initiative in the neurobiology of learning and memory will continue to include increased support for multidisciplinary research teams, and the establishment of a small number of multidisciplinary research and resource centers. Greater elucidation of the neural structures and processes which underlie the phenomena of learning, memory, and information utilization continues to be the goal of this research.

Studies of organizational effectiveness are another major cross-disciplinary effort needing enhanced support. Research on structural constraints to effective use of human resources, management decision-making, small group interactions, and organizational evolution will produce information to help America respond to the many economic productivity questions it faces, e.g. organizational resistance to high-tech innovation adoption and the impact of organizational morale on productivity. An attempt will be made to create a data base from a national sample of organizations which will allow for tracking over time of changes in structure and effectiveness. Sociologists will be able to conduct cross-level analyses comparing individual-level data with organizational-level data. Economists will pursue the development of a conceptual paradigm to explain organizational effectiveness through the use of game theory models, institution design mechanisms, and public choice models. Payoffs from this basic research can already be seen in deregulation activities and in acceptance by businesses of worker profit sharing as an incentive for low unemployment and greater productivity. (The latter also became a major plank in a presidential campaign this year.) Interdisciplinary studies of behavioral theories of business firms will also lead to better understanding of organizational performance.

These initiatives in geography, decision, risk and management science, psychobiology, and organizational effectiveness are significant indications from NSF that the social and behavioral sciences are an important part of the Foundation's agenda for economic competitiveness. All were adversely affected by the reduction from the FY 1988 request in the FY 1988 appropriations. Granting the full increment for Research and Related Activities for FY 1989 will allow these important research initiatives to go forward without curtailing ongoing projects in the social and behavioral science disciplines, including support for large scale, multi-user data bases such as the Panel Study of Income Dynamics, the General Social Survey, the National Election Studies, and the Supreme Court Data Base, which provide researchers and public policy makers enormous amounts of useful information.

In addition, the proposed budget provides for increased support for social and behavioral science research on global change. A major international effort to expand our understanding

of this phenomenon is underway. Groups such as the American Association for the Advancement of Science, Sigma XI (The Scientific Research Society), the International Conference of Scientific Unions, and the International Social Science Council, are involved in seeking answers to this worldwide challenge. Social and economic research in this area will enhance comprehension of the effect of public policies, regulation and industrial and agricultural policies on the biology, chemistry, and geology of the earth. This is also an area where the social and behavioral sciences will interact with the natural and physical sciences to produce significant solutions to an important problem. Support for NSF's full FY 1989 request will sustain this effort.

COSSA also supports increased funding for the Studies in Science, Technology, and Society program in the new Division of Instrumentation and Resources. Interdisciplinary research on history, philosophy, social, and ethical issues of science and technology reveals where we have been, how we got where we are, and the methods we can live with to get where we are going.

Concern has been raised in many places about NSF's move to encourage the development of science and technology centers, often perceived at the expense of individual investigator-initiated research. COSSA is concerned as well. For many of the social and behavioral science disciplines, the individual investigator remains the key to significant basic scientific research. Yet there is a place for centers in these disciplines as well. The Foundation has received 325 proposals for its Science and Technology Centers program. A number of these are in the social and behavioral sciences, and a significant number is in the multidisciplinary fields of cognitive science and artificial intelligence. We ask the Subcommittee to fund the Centers at the requested level so the Foundation will not have to sacrifice the individual investigator to save the Centers program or vice-versa. We also still believe the Subcommittee should keep a wary eye on this situation since the long-term effects of support for such centers is unknown.

This is one of the reasons we would continue to support an ongoing role for the authorization committees in their relationship with NSF. Congressional oversight through the authorization process remains an important check on the agencies of the executive branch. Checks and balances should be reinforced. The Committee should act with caution in moving to a five-year authorization for the Foundation.

COSSA also supports the 12% increase proposed for the Science and Engineering Education Directorate. It represents a further step in the reinvigoration of that directorate. The proposed increase in the number of graduate fellowships will enhance the development of a new generation of scientists and researchers to produce the knowledge of tomorrow. We agree with NSF's strategy to provide resources for undergraduate education within the disciplines. This is the best means for the

integration of research and training for undergraduate social and behavioral scientists. We also applaud the increase for research in teaching and learning, an arena in which behavioral scientists play an important role.

The significant research achievements of social and behavioral scientists are well known to this Committee. You have demonstrated time and again your belief that these accomplishments are important to the scientific enterprise within the United States. The Congress continues to call on us to present the results of our research to provide the information that will help policy makers make decisions. In the first 3 months of the 2nd session of the 100th Congress close to 80 university-based social and behavioral scientists have been witnesses before Congressional committees. We cannot continue to offer this expert advice without support for the basic research we carry out. We ask you to support our future efforts by giving NSF its full FY 1989 budget request.

Thank you this opportunity to present our views.

STATEMENT OF DR. RICHARD A. ANTHES, ACTING PRESIDENT, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Mr. Chairman, the University Corporation for Atmospheric Research appreciates the opportunity to submit this statement for the record discussing the National Science Foundation authorization for fiscal year 1989 and beyond.

The University Corporation for Atmospheric Research (UCAR), headquartered in Boulder, Colorado, is a consortium of 57 institutions of higher education in North America. UCAR includes virtually all U.S. universities with Ph.D. programs in the atmospheric, oceanic and related sciences. The consortium has been in existence for 29 years, and is organized as a private, not-for-profit Colorado corporation. A list of our 57 member institutions is attached to this statement (Attachment 1).

UCAR operates the National Center for Atmospheric Research (NCAR) under the sponsorship of the National Science Foundation, the Institute for Naval Oceanography under the sponsorship of the U.S. Navy, and conducts other programs with Federal support to advance the nation's research, education and technology efforts.

NCAR, also located in Boulder, Colorado, has several interrelated missions.

The first is to identify, plan and carry out, in collaboration with scientists of the national and international communities, research projects on problems of national and international scope and importance. The importance is measured not only in scientific terms but also in the ultimate potential for useful application of the knowledge produced.

The second is to identify, develop and provide to the atmospheric sciences community advanced research facilities required to make progress on these important atmospheric problems. The facilities include supercomputers, specially instrumented research aircraft, Doppler radars, and other observational facilities.

Finally, NCAR is a planning center where the world's leading atmospheric scientists gather to determine the most promising strategies for attacking the large problems of the atmospheric sciences. This includes an important educational aspect: NCAR introduces undergraduate and graduate students and postdoctoral fellows and faculty to research and sponsors vigorous programs at each level.

NCAR conducts research in the following areas: the dynamics of weather and climate; clouds and cloud complexes that produce most of our severe weather as well as much of our beneficial rain and snow; the chemistry of the atmosphere on global and regional scales, including such man-induced phenomena as acid rain, global climate change, and ozone depletion; and the interactions among the atmosphere, the oceans, plant and animal life and the sun.

All research efforts are developed in concert with the university community and reviewed by the National Science Foundation to respond to national needs.

I will now turn to your request to discuss the Administration budget request for the National Science Foundation for fiscal year 1989 and beyond.

The National Science Foundation Budget Request for FY89

The National Science Foundation budget request for FY89 is $2.050 billion, representing an increase of $333 million, or 19% over the FY88 level. This includes a 10% increase for Research and Related Areas, from $1453 million in FY88 to $1603 million in FY89. In addition, the authorization bill which you have under consideration, S.1632, calls for a five-year authorization, an action which we feel is extremely important to help assure consistency and stability for scientific research funding and technology tranfer to the private sector. The bill contains a significant increase in funding through FY90, and then "such sums as may be necessary" for the years FY91 and FY92. We would prefer to see actual funding amounts for those two years to ensure support for the increases necessary to achieve a doubling of the NSF budget in five years. However, the proposed five-year authorization is a welcome development, and we hope the Committee can support it.

The reasons why the increase in funding for FY89 and a doubling of the budget in five years are important include the following points:

1. Our trade balance is overwhelmingly negative and has been for many years. Yet the markets we must compete in have become international. In order to be economically competitive, experts agree that we must have high productivity. U.S.

productivity levels, based on Department of Labor statistics, have been disappointingly small, averaging about 0.3% annually, while our primary competitors, especially Korea, Japan, Germany, France, and Great Britain, have done 5-15 times as well.

2. New technology has been largely responsible for almost half of all productivity increases since World War II, yet the Federal government's investment in the civilian, university-related research necessary to maintain new technological development is far less, as a fraction of GNP, than efforts in Japan and Germany, for example. Federal support of university research, according to the Packard Report, peaked in 1968 and bottomed out in 1978. After some small increases in 1979 and 1980, it continued to decline into the 1980s until recently. This decline, according to the Packard Report, is reflected in a significant deterioration in the United States' ability to promote technological advances and compete in the international marketplace.

3. Enhanced research support in basic science is needed to deal effectively with complex, often multidisciplinary problems affecting the environment of both this nation as well as the world. These problems include severe weather of many types that affect the safety and basic economic well-being of individuals as well as nations; the degradation of the environment in areas such as acid rain and ozone depletion that can have both direct and indirect affects on health as well as biological and agricultural outputs; and other potentially serious disruptions in temperature and rainfall patterns associated with changes in the global environmental systems. This research, involving the need for better data bases and models, is needed not only to minimize adverse economic and social effects associated with these changes in our environment, but also to enable our society and you, the Congress, as part of the policymaking structure, to make the difficult choices necessary affecting our agriculture, transportation systems, infrastructure, natural resources -- indeed, choices potentially affecting our economic order as we know it today.

New Collaborations with Industry

In keeping with the National Science Foundation's priority to provide greater technology transfer to industry, UCAR has been breaking new ground in taking results of basic research and deriving economic and commercial benefits from them for the U.S. business sector. We have developed a special program of interaction and collaboration with U.S. industry called the Corporate Affiliates Program (Attachment 2 lists the industry members of this program). Through this program, we provide ready access to the most recent knowledge about climate, weather and other atmospheric issues of special interest and importance to

our business members. The program also brings corporate executives and researchers together with leading scientific authorities who are working at the frontiers of the atmospheric, ocean, space, computer, and related sciences, as well as with other experts, to assess the practical, economic, and social consequences of atmospheric conditions.

We have created the new UCAR Foundation, a subsidiary nonprofit effort, to foster the spinoffs of these new relationships between the business and research communities. Some of the new collaborations and relationships that have developed are listed below.

(1) Digital Equipment Corporation is currently engaged in a joint venture involving UCAR's Unidata Project, a national program to aid universities in accessing, analyzing and displaying a wide range of atmospheric data for use in both education and research. Digital has provided staff and equipment support to UCAR and is receiving considerable scientific and technical input in scientific computer applications from UCAR. In addition, a joint UCAR/Digital Equipment Corporation graphics visualization project has been approved by both organizations and will be underway shortly.

(2) **Airport of the Future.** The MITRE Corporation has recently joined with UCAR in launching the newly developed **Airport of the Future** project aimed at producing a prototype design for a weather forecast and information system that will significantly improve the safety and efficiency of major airport operations. MITRE has provided staff and technical expertise to further the project's development. MITRE is also granting the UCAR Foundation rights to an Expert System (Artificial Intelligence) which is becoming effective forecasting snow at Denver's Stapleton Airport. The system will become part of the project. In addition, US West Advanced Technologies, Inc. has contributed funds and manpower to the UCAR Foundation for participation in the **Airport of the Future** project. This part of the project will produce a series of reports for the City and County of Denver relating to the overall weather forecast system that will be built in conjunction with the new, multibillion dollar Denver airport. This information should have important ramifications for all major airports in the United States as well as throughout the world.

(3) IBM and NCAR's supercomputing division will be working on new methods of sharing large data bases between different computers. IBM is also playing a key role in marketing the NCAR Mass Storage System through a subsidiary company formed by UCAR, MESA Archival Systems, Inc. MESA was created to commercialize UCAR supercomputer intellectual properties.

(4) External Tanks Corporation (ETCO) was founded in 1985 to develop plans for using the External Tanks of the Space Shuttle Fleet as scientific and commercial platforms in space. A half million dollars in private capital has been raised in the first phase and is being used to develop plans for a variety of purposes.

Other collaborations between UCAR and U.S. industry are being developed involving computing, radars, and other airport systems.

Many of these developments are now or soon will enhance U.S. computing capabilities, aviation safety, safety of lives and property from severe weather, and U.S. industrial development. But none of it would have been possible without the basic research dollars invested by the Federal government through the National Science Foundation and other Federal agencies. With the additional support for the NSF, we can expect the tempo of these collaborations with U.S. industry to increase.

Mr. Chairman, we appreciate this opportunity to provide our views for the record.

End

American Chemical Society

OFFICE OF THE
PRESIDENT

Gordon L. Nelson
President-Elect, 1987
President, 1988
Immediate Past President, 1989

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April 14, 1988

The Honorable Ernest F. Hollings
Chairman
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

The Nation's technological competitiveness depends significantly upon continued long-term support for basic research and education at our universities and colleges. Without such support, the U.S. cannot extend the knowledge base of the basic sciences and engineering, which lays the foundation for innovation and new product development. Nor can the U.S. train and educate the next generation of scientists and engineers who will be needed to develop products, to perform research, and to restore scientific literacy. To provide the necessary support for a healthy academic system and to ensure a continuing supply of scientifically trained employees for industry's needs, the American Chemical Society (ACS), recognizing the existing bipartisan support for these goals, strongly urges the Subcommittee to begin a five-year doubling of the National Science Foundation's budget in FY 1989.

The research disciplines have lost valuable ground due to budget constraints over the past three years. A healthy discipline is built on research conducted in the core fields and at the frontiers of science; it depends upon adequate instrumentation and facilities. For fifteen years, U.S. investment in civilian R&D as a percentage of GNP has lagged far behind that of West Germany and Japan, and the difference is growing. Now France has passed the U.S.

The Society is pleased that there are proposed increases for the NSF Divisions of Chemistry, Materials Research, and Chemical, Biochemical, and Thermal Engineering. ACS is supportive of the new and continuing interdisciplinary research thrusts, as well as the cross-directorate human resource and education initiatives that are funded in them. However, after three years of budget constraints, the underfunding of base research programs is growing and must be rectified.

The individual researcher and established research groups are hard-pressed for funding. They are looking to the FY 1989 budget for funding to address the research opportunities before them. With this in mind, the American Chemical Society makes the following recommendations:

- In order to exploit the enormous research potential in the chemical sciences and technologies, the ACS recommends that $4.5 million be added to the budget request for the Chemistry Division, and that an additional $3.0 million be added to the budget request for the Materials Research Division, as a first step towards

providing adequate support for individual investigators. The funding level proposed for the Chemical, Biochemical, and Thermal Engineering Division should be viewed as the minimum level necessary in the fields supported.

- The Society supports the Science and Technology Centers program, at the requested level of $150 million, as a viable method of funding research. However, should budget constraints occur, funding for the S&T Centers should not come at the expense of the Foundation's requests for individual investigator research. The program also should be monitored closely by the Office of Science and Technology Centers in order to measure its contribution to the health of the sciencea and its impact on the research base.

The American Chemical Society supports the concept of federal funding for repair, renovation, and replacement of aging university facilities. Just as a highly skilled instructor is important to quality education, a state-of-the-art laboratory is important to research advances. There is a large and growing recognition of the need for funds to build and modernize scientific research laboratories. The provision for facilities funding contained in the Senate Authorization bill for the Foundation, including cost-sharing requirements, is a necessary first step in addressing this issue. The Society strongly supports merit-based review to select the highest quality research facility projects.

An effective system of science and engineering education is vital to the long-term interests of the United States. The Nation is falling behind developed and developing countries in the quality of scientific education. Science literacy is declining. Our prosperity and national security depend on having enough well-trained scientists and engineers to respond to national needs. Therefore, the American Chemical Society recommends:

- An increase of $50 million in FY 1989 be allocated to the Science and Engineering Education (SEE) Directorate to address the problems of teacher retraining and recruitment, instrumentation needs, and minority and female recruitment into the sciences. SEE is the primary focal point for NSF's educational activities. Since its reinstatement in 1985, the Division has labored to match its past levels of effort. This increase will begin a steady march toward that goal. The additional funding requested by ACS is $33 million above the budget proposed by the Administration and should be new monies added to the Foundation's budget proposal.

The accompanying Appendix provides greater detail on the Society's recommendations. The ACS believes that the work accomplished by the Foundation contributes to the economic well-being of our Nation. Thus, it is imperative to provide increased support to the National Science Foundation even in a time of budget constraint.

Sincerely yours,

Gordon L Nelson

Gordon L. Nelson

Appendix

cc: Other Members, Senate Committee on Commerce, Science, and Transportation

APPENDIX

The Nation's future research capability depends upon the teaching and education afforded to our students through government-sponsored research. Our industry's ability to compete rests upon the technological advances made through basic research. Central to these activities is the National Science Foundation, which funds research and education activities at all levels, and is the principal funding source for nonmission-oriented basic research. Recognizing the existing bipartisan support for improving these areas, the American Chemical Society strongly supports a five-year doubling of the NSF budget beginning this year.

While the Foundation's budget is slated to increase 19 percent in FY 1989, the Research and Related Activities (R&RA) category, however, is scheduled to increase by only 10 percent. Nearly 60 percent of the funding within R&RA will support individual investigators--a single researcher in a laboratory with graduate students. Much of our national scientific advancement has grown from these roots. The funding received by these individual investigators benefits not only the research and the student, but the institution as well, strengthening and improving the U.S. education enterprise nationwide.

Individual investigators are aware of NSF's attempt to begin doubling its budget in FY 1988. They also are painfully aware that that goal was not achieved. For FY 1988, R&RA received a 3 percent increase, somewhat less than inflation.

The health of academic research and education in chemical sciences, materials science, and chemical engineering is essential to continued U.S. economic competitiveness, particularly in the chemical and allied industries; a sector of the economy that has a growing positive trade balance. This strong showing is related to the academic infrastructure that supports it.

NSF is a primary player in assuring continued competitiveness through its funding of: (1) 40 percent of all the academic chemistry research sponsored by the federal government; (2) 84 percent of all the federally-funded academic chemical engineering research; and (3) about 50 percent of all the academic materials research conducted with federal funds.

The ACS is discouraged that modest increases are proposed for these fields in NSF's FY 1989 budget request. The 5.2 percent increase in the Chemistry Division and the 7.2 percent increase in the Materials Research Division will not allow researchers to exploit the opportunities before them. The Society is pleased that the Chemical, Biochemical, and Thermal Engineering Division does receive a 10.4 percent increase. Synergism exists among these fields, and extends to joint initiatives at the research frontiers. The comments that follow focus on the individual NSF divisional activities first, then on the synergistic relationships.

Chemistry Division

The FY 1988 budget for the Chemistry Division increased one-half of one percent (0.5 percent) over FY 1987. Although the dollar amount of the Division's awards are equal to the FY 1987 level, fewer awards actually will be made. For those who received awards or renewals of current grants early in FY 1988, the dollars received were less than expected. Programs are being operated at reduced levels--inorganic,

Bioinorganic, and Organometallic Chemistry; Organic and Macromolecular Chemistry; Physical Chemistry; and Chemical Instrumentation are below the FY 1987 level of support. Chemical Instrumentation, in fact, is operating at less than the 1984 support level. Given the current funding level, it is unlikely that the Chemical Instrumentation Program will be able to continue to fund maintenance of large-scale instrumentation, a plan that just began this year. The Society strongly urges the Foundation to take every effort to bring the Chemical Instrumentation Program back to the equivalent level of funding that was available in FY 1987. State-of-the-art, shared-use equipment in our Nation's university laboratories is crucial to the health of the U.S. research enterprise. It is essential that NSF continue its strong support in this area.

The FY 1989 budget request includes a 5.2 percent increase for the Chemistry Division. While the FY 1989 budget increases support for new, interdisciplinary research initiatives in materials chemistry, the ACS is concerned that these initiatives are being pursued at the same time that disciplinary research is being underfunded.

Finally, the Society commends NSF for its initiation of the Postdoctoral Fellowships in Chemistry awards. These are three-year awards that may be converted, in their final year, to academic starter grants. The ACS regrets, however, that this program was only able to move forward in 1988 at one-half its intended level. The American Chemical Society supports the $1.5 million FY 1989 increment for this program and hopes to see continued emphasis within the Division for these awards.

Materials Research Division

In the Materials Research Division a similar pattern of erratic funding is found. While the proposed FY 1989 budget increases 7.2 percent, that increase follows three years of small but variable increases. In FY 1986, the budget decreased due to sequestration under the Gramm-Rudman-Hollings law. In FY 1987 and FY 1988, the budget increased 4.3 percent and 2.1 percent, respectively, yet this represents only one-third and one-fifth of the increases requested to meet the Division's needs, due to increased academic research proposals in this area.

The FY 1988 budget increase is below inflation and only permits operation of some programs at their FY 1987 level or below. The Materials Research Groups program will fund one of the three to four additional groups originally planned in 1988. The Materials Research Instrumentation Program was cut 18.5 percent in FY 1988, bringing instrumentation funding to below 1984 levels. As with instrumentation funding in the Chemistry Division, ACS urges that every effort be made to restore this program at least to levels equivalent to FY 1987.

The Materials Research Division supports numerous activities that are on the forefront of high technology, notably, solid state chemistry, polymers, and ceramic and electronic materials. NSF is, in fact, the predominant source of federal funding in solid state chemistry since the Department of Defense funding for basic research has declined. The seriousness of this situation in the Materials Research Division is evidenced in the lost opportunities that are stymieing polymer research.

During the past twelve years, the number of academic investigators has risen from about 200 to over 850; yet individual investigator proposals funded during the same period have declined from 94 to 92. Funding needs in basic polymer research are not being met.

ACS is pleased that the Materials Research Groups program is slated to receive a 20.3 percent increase in FY 1989. The proposal pressure in this program has been increasing since its inception in FY 1985. That year, NSF received nineteen proposals and funded five groups. In FY 1986, the Foundation received thirty-one proposals and again funded five new groups as well as one Materials Research Laboratory that had been down-graded. In FY 1987, thirty-two proposals were received, but only three new groups were funded, along with another down-graded Laboratory. Only one additional group will be funded in FY 1988, out of twenty-six that have sent in proposals. On an average, a Materials Research Group supports six investigators, and six to eight graduate and undergraduate students. The FY 1989 increase slated for the Materials Research Groups program will enable the Foundation to continue support for existing groups while funding three to four new additional groups.

Chemical, Biochemical, and Thermal Engineering Division

After Gramm-Rudman-Hollings sequestration occurred in FY 1986, the budget for the Chemical, Biochemical, and Thermal Engineering (CBTE) Division did not increase substantially: the FY 1987 budget maintained programs at the FY 1986 level. Because of the late action on the FY 1988 budget, CBTE programs again increased very little, leaving investigators working near FY 1988 levels of support. The impact of these funding patterns becomes more worrisome when one considers that 84 percent of federal support for basic research in chemical engineering conducted at universities and colleges comes from NSF.

Research initiatives within CBTE focus on areas important to our manufacturing technologies. The research supported impacts on biotechnology, electronic materials, pharmaceuticals, polymers, specialty chemicals, semiconductors, and ceramics. It is imperative that these funding levels be given priority in this and future NSF budgets.

ACS is pleased to see the Foundation's emphasis on combustion processes relating to the incineration of wastes. Novel concepts that will lead to advances in the thermal destruction of dangerous compounds are needed. Current research on uniform deposition of thin films for microelectronic chip production are being supported, as well, by CBTE. Research in this area can ultimately benefit our high-technology industries by eliminating the need for elaborate control systems, thereby reducing ultimate production costs.

Interdisciplinary Research

Chemistry is a central science that leads and supports research in numerous fields--from biotechnology to microelectronics. Chemistry's contribution to high-

technology industries is wide-spread. A synergistic relationship exists among chemistry and other fields, notably with materials research, biology, physics, and engineering. These relationships are manifested in interdisciplinary efforts.

The Materials Chemistry Initiative, for example, is supported by the Chemistry; Materials Research; and Chemical, Biochemical, and Thermal Engineering Divisions, with a total combined funding of $19.6 million in FY 1989, a 24.8 percent increase. Included as part of this initiative is superconductivity research, materials with designed properties, and chemical processing of advanced materials and devices for information storage and handling.

The American Chemical Society commends the long-term support that the Materials Research Division provides in the field of superconductivity. Fourteen years of continuous support enabled Dr. Paul Chu's research team at the University of Houston to make the advances in superconductivity that made international headlines. However, much remains to be done. ACS supports the emphasis placed on superconductivity in FY 1989--a $2 million increase for that area to $14.5 million in the Materials Research Division. Overall, the Foundation will provide $20.1 million for superconductivity research, including $0.75 million in the Chemistry Division, $2.5 million in the Physics Division, and $2.2 million in the Engineering Directorate. Some funding will be part of the Materials Chemistry Initiative, supplemented with individual investigator grants.

Superconductivity has captured the imagination of the American people and it has demonstrated the need for long-term support of basic research. However, the Society is concerned that the small increment in the Chemistry Division will not be sufficient to permit in-depth studies on the characterization of superconducting materials. The Society hopes that this increment will increase substantially in FY 1990.

The ACS supports the additional research thrust within Materials Chemistry on "Chemical Processing of Advanced Materials and Devices for Information Storage and Handling." This initiative will be managed jointly with the Chemical, Biochemical, and Thermal Engineering Division, and possibly other divisions. Among the important research areas to be explored are the preparation and characterization of thin films used in making electronic, optical, and magnetic devices that store and handle information. Interfacial phenomena studies will help us understand the layering formations important to high-quality materials. Other studies will enable us to further our knowledge of available materials and to make more compact structures for information storage and handling.

The Society also notes the continued emphasis on another initiative, Chemistry of Life Processes, which was proposed in a 1985 National Academy of Sciences/ National Research Council report, Opportunities in Chemistry. Research in Chemistry of Life Processes is conducted by the Chemistry Division in conjunction with the Biological, Behavioral, and Social Sciences Directorate. Areas supported include the chemistry of the senses and studies of large-molecule/small-molecule binding and recognition. The Chemistry Division supports additional single-investigator projects that complement these collaborative projects.

Benefits of Research and Future Research Directions

Opportunities in Chemistry emphasized five broad areas of research that require priority funding--understanding chemical reactivity, chemical catalysis, chemistry of life processes, chemistry around us, and chemical behavior in extreme conditions. Chemistry has been and continues to be underfunded to meet new research directions. Although the Society can cite discoveries, we can only wonder at the opportunities lost due to a lack of adequate funding.

Dr. Donald Sawyer at Texas A&M has discovered a new chemical method that destroys polychlorinated hydrocarbons, such as PCB's. The most environmentally persistent of these usually contain the most chlorine, yet Dr. Sawyer's new method would destroy these compounds more easily. His discovery has a broad impact on environmental chemistry.

Professor Donald Cram, UCLA, received the 1987 Nobel Prize in Chemistry for his research on "host-guest" chemistry. His research focuses on the ability of large molecules to recognize and capture small molecules. These large molecules mimic naturally-occurring substances called enzymes that influence chemical and physical reactivity. This landmark research, which will impact on technologies such as separations, catalysis, and molecular biology, would not have been possible without the thirty years of continuous support received from the Foundation's Chemistry Division, among others.

In June 1988, the National Research Council is scheduled to publish a report, similar to the 1985 Opportunities in Chemistry report, that will address the needs in the field of chemical engineering--"Frontiers in Chemical Engineering: Research Needs and Opportunities." This Report will identify areas of research that can provide the U.S. with a technological lead in the next decade and beyond. Areas of emphasis for NSF include:

- electronic, photonic, and recording materials;
- polymers, ceramics, and composite materials;
- separation and purification research;
- environmental protection, process safety, and hazardous waste management;
- surface and interfacial engineering;
- biotechnology and biomedicine;
- computer-assisted process and control engineering; and
- processing of energy natural resources.

Because of the large proportion of support provided for basic research in chemical engineering by NSF, the Foundation must play a leading role in the advancement of these research areas.

Recommendations for Research Divisions

Research support in the chemical sciences and engineering is central to our Nation's economic growth. The research performed is beneficial to our leading

industries--pharmaceuticals; organic, inorganic, and specialty chemicals; resins; rubbers; fertilizers; and plastics. The Chemical and Allied Products sector has consistently maintained a positive trade balance with foreign nations. Last year, Chemical and Allied Products exported $9.3 billion more products than were imported.

These industries are research intensive. They rely not only upon the innovations made in our Nation's universities and colleges, but also upon educated scientists and engineers who can bring fresh insights and experiences to these industries. More than ever before, it is essential to maintain and improve the research base in the chemical sciences, and the Foundation must play the key role in this area.

The ACS is pleased that there are proposed increases for the Divisions of Chemistry; Materials Research; and Chemical, Biochemical, and Thermal Engineering. The Society is supportive of the new and continuing interdisciplinary research thrusts in these Divisions, as well as the cross-directorate human resource and education initiatives that are funded in the research divisions. These research initiatives and foundation-wide programs have a justified claim on increases proposed in the FY 1989 budget. However, after three years of budget constraints, the critical base research programs are underfunded and the individual researcher and established research groups are hard-pressed for current funding.

- ACS recommends that an additional $4.5 million be added to the budget request for the Chemistry Division, to enable NSF to program additional funds to the core disciplinary research areas and instrumentation, which are underfunded.

- Considering the great research strides emanating from the Materials Research Division, ACS recommends that the Division receive an additional increase of at least $3 million above the FY 1989 request. The Society recognizes that additional monies would advance basic research in this area and strongly urges the Foundation to consider the importance of this field in its preparation of the FY 1990 budget.

- The research areas outlined in the soon-to-be-released National Research Council report present the Chemical, Biochemical, and Thermal Engineering Division with the opportunity to move into critical new avenues of study. To the extent possible, ACS recommends that funding be made available for these promising research areas, through internal readjustments within the confines of the proposed FY 1989 budget. Future budgets should be prepared with these needs in mind. In FY 1990, an increment of $12 million will be necessary to begin implementation.

Science and Technology Centers

The American Chemical Society believes that it is appropriate that a separate line item be created for the S&T Centers. The request of $150 million will provide support for twelve to fifteen centers in FY 1989 and assure continued funding for up to five years. To date, the National Science Foundation has received 325 proposals totaling $4.1 billion for the total five year period.

ACS commends NSF for the creation of the S&T Centers Coordinating Office, which will enable NSF to monitor the program carefully. Questions relating to the evaluation and lifetime of the centers must be addressed. The separation of the S&T Centers from the research divisions will enable NSF to measure the impact of the Centers on other modes of research funding, especially individual investigators and groups, a task in which NSF must be especially diligent.

ACS agrees with the finding of the National Science Board, the Foundation's advisory board, that the balance between centers and individual investigators should be determined by the requirements of the science and engineering enterprise. Although ACS firmly believes that the individual investigator is the appropriate mode of support in most fields of endeavor, the Society recognizes that the center concept may provide long-term support in some areas that demand additional funds. The centers concept may contribute to the number of investigators entering cross-disciplinary fields by encouraging students to complete doctoral studies in these emerging fields.

These centers may provide the incentive for creative interactions that can lead to scientific discovery. ACS supports the requested budget of $150 million; however, should budget constraints occur, funding for the S&T Centers should not come at the expense of the Foundation's requests for individual investigator research.

Facilities

The American Chemical Society supports the concept of federal funding for repair, renovation, and replacement of aging university facilities. Just as a highly skilled instructor is important to quality education, a state-of-the-art laboratory is important to research advances. There is a large and growing recognition of the need for funds to build and modernize scientific research laboratories. The provision for facilities funding contained in the Senate Authorization bill for the Foundation is a necessary first step in addressing this issue.

ACS notes that this legislation would require cost-sharing. In the past, funding has been obtained by academic institutions from a variety of sources--alumni donations, foundation and corporate grants, and state and federal government awards. The Society believes this mixture also should be the preferred method for obtaining future funds. While no one should expect the federal government to solve single-handedly the facilities problem, the reality of other sources must be throughly examined, particularly for state institutions.

The American Chemical Society strongly supports merit-based review to select the highest quality research facility projects. In addition to the quality of proposed research and the competence of the investigators, merit review also should give consideration to the effect of the project on the research infrastructure, and to the contributions the project will make towards the related goals of equity and distribution of resources among institutions and geographic areas. The review should consider the scientific merit of the research to be funded, as well as the project's linkage to technology transfer and to community and economic development.

This review process is currently the most equitable way of guaranteeing careful scrutiny of, and excellence in, federally-funded basic research projects. The Society is cognizant of the special provisions in the bill that will assist institutions that have received less than $10 million in Federal research and development funding in the preceeding two years. ACS believes this set-aside to be an essential means by which smaller institutions can compete for facilities funding.

The Society supports the proposed authorization of $47 million in FY 1989 for a facilities program as a first step toward revitalizing our university infrastructure. Depending on how these monies are administered, however, the Society cautions that federal funds used for this university facilities modernization program ought not to erode the direct federal funding of R&D activities at our Nation's colleges and universities. Any reduction of the funds available for basic scientific research would be of grave concern to the ACS.

Science and Engineering Education Directorate

Given the continuing need for strengthening our national commitment to science and mathematics education, the Society is disappointed with the small increase in the Administration's FY 1989 request for the SEE Directorate. The proposed amount can not maintain the current momentum of Directorate programs, nor can it allow for the establishment of new programs vital to the success of NSF's congressionally chartered mission.

The well-documented crisis in U.S. science, engineering, and mathematics education is still with us. No one should assume that a few years of concern will compensate for many years of neglect. Nor should it be assumed that the problems now facing science, engineering, and mathematics education are in any way less serious than the problems of science and mathematics education in the mid-1960's. As stated in the 1988 report of the International Association for the Evaluation of Educational Achievement, the United States lags significantly behind many other countries in student achievement in the sciences for 5th, 9th, and 12th grades. In chemistry achievement, for example, the United States was ranked eleventh out of thirteen countries; 48 percent of U.S. high schools scored lower than the lowest schools in the highest ranking countries (England, Hong Kong, and Singapore). This situation is a shocking indictment of what was once the model school system, admired and emulated by the rest of the world.

If the U.S. does not solve its current educational problems and ensure that they do not recur, the Nation faces critical shortages of scientific manpower that will seriously impair economic productivity and destabilize its security well into the next century. Yet the level of support for SEE Directorate programs under the FY 1988 Current Plan is only one third of the level of support, in constant 1988 dollars, for education in the FY 1968 NSF budget--and there are 50 million more Americans to educate (See Attachment). As Congress itself has noted, the NSF education programs have been "short changed" for almost twenty years and there is an urgent need to "catch up".

In view of the Nation's precarious position, the American Chemical Society recommends that, for FY 1989, the SEE Directorate be authorized at a much higher level than the Administration request. An increase from FY 1988 to FY 1989 of at least $50 million is needed. Further, in concurrence with recommendations from two National Science Board reports, Educating Americans for the Twenty-First Century and Undergraduate Mathematics, Science, and Engineering Education (the "Neal" Report), the Society believes that the total effort of the SEE Directorate should rise to $600 million over the next four years, as part of the planned increase in the NSF budget.

The ACS heartily supports the efforts of the SEE Directorate to devise programs that address the full spectrum of science literacy concerns, as well as the more traditional science career programs. Science cannot flourish in a society where the majority of its citizens do not understand either the scope or the limitations of science as a solver of societal problems; and have neither the knowledge, nor the comfort level, necessary to address science and technology issues that impact upon the community.

The SEE Directorate's emphasis on materials development and informal science education at the elementary and middle school levels is very appropriate given the established importance of successful science experiences in the early years. Such experiences contribute to a greater appreciation of the nature of science, and to a larger available talent pool from which the scientists of the future will emerge.

However, programs planned for FY 1989 do not appear to be funded well enough to address the issues of teacher retraining and shortages. Given the aging population of current science and mathematics teachers, and the very few science and mathematics students electing to join the teaching profession, the ACS recommends that additional funds be made available to tackle these particular problems. To encourage entry into the profession, one approach would be to develop a Presidential Young Teacher's Award, analogous to the Presidential Young Investigator's Award, to support the training of undergraduates electing to become science and mathematics teachers. Such a program would do much to recognize that new, well-educated, highly motivated teachers are just as important to science as are new, well-educated, highly motivated researchers. The Presidential Awards for Excellence in Science and Mathematics Teaching recognize the contributions of current teachers but are not a sufficient motivator to attract new teachers into the profession.

The Society is pleased that the College Science Instrumentation Program is being administered for instructional as well as research purposes. The ACS reaffirms its previously stated position that this competition should be conducted each year, and that each year it should be open to two-year colleges, four-year colleges, and research universities. The need for this program is evident given the large number of unfunded proposals in FY 1988. All institutions of higher learning have need for undergraduate instrumentation. The proposed level funding for FY 1989 of $11.5 million is clearly inadequate. It should be noted that the Neal Report recommends an annual outlay of $30 million for instructional instrumentation and equipment.

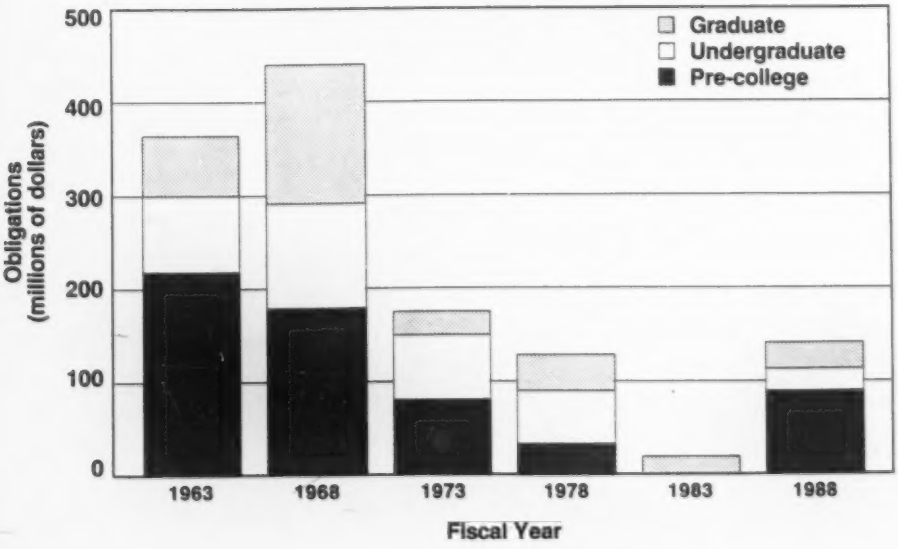
The American Chemical Society supports the expansion of undergraduate programs to more than $60 million in FY 1989. However, the Society notes that only $4.5

million in new money is assigned to the SEE Directorate for a total of $23.5 million in FY 1989. The Society again would like to cite the Neal Report which recommends a $100 million budget for undergraduate education in FY 1989 and designates the SEE Directorate as the lead organizational unit. The current coordinating function of the Office of Undergraduate Science, Engineering, and Mathematics Education does not meet the intent of that Report.

The ACS has learned that even with a decrease in proposed funding being planned, an additional 100 Graduate Fellowships will be awarded in 1989 through a change in accounting procedures. The Society notes that the SEE budget will have to increase in subsequent years just to meet these current obligations.

Finally, the Society fully supports the special emphasis of the Foundation on minority and female recruitment into the sciences. However, given the high exodus of minorities from the educational pipeline before 12th grade, and the disastrous pattern of mathematics and science coursetaking by minorities in high school, intervention should most effectively be targeted at the elementary and middle school levels. Support at the graduate, or even undergraduate, levels is well-meaning but probably too late to substantially increase the population of currently underrepresented minorities in science, engineering, and mathematics. Because of demographic projections into the next century, increasing the representation of these minorities in the quantitative disciplines pool goes beyond equity issues to the very survival of the scientific enterprise as it is recognized today.

April 14, 1988

Science and Engineering Education

Obligations by Level of Education (in constant FY88 dollars)